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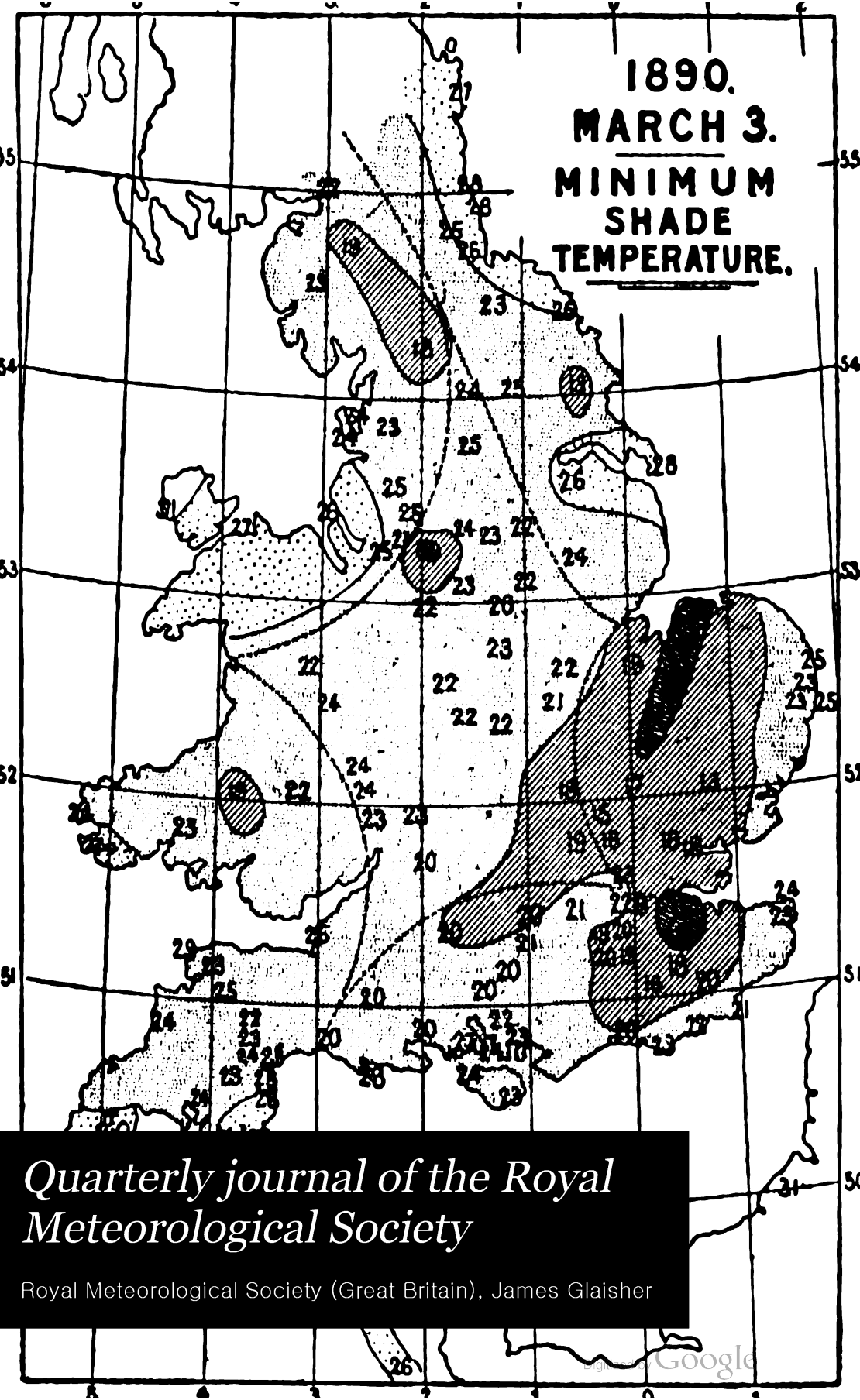
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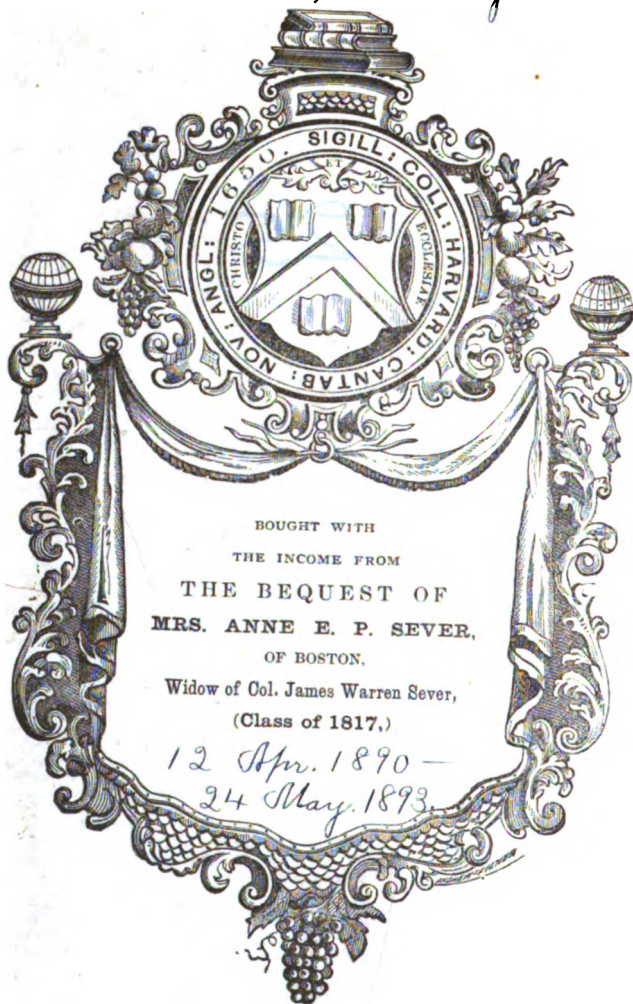


*Quarterly journal of the Royal
Meteorological Society*

Royal Meteorological Society (Great Britain), James Glaisher

Sci 821.5

Bd. June 1894.



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QUARTERLY JOURNAL
OF THE
ROYAL
METEOROLOGICAL
SOCIETY.

EDITED BY
A COMMITTEE OF THE COUNCIL.

VOL. XVI.
1890.

LONDON:
E. STANFORD, 26 & 27 COCKSPUR ST., CHARING CROSS, S.W.;
WILLIAMS AND STRAHAN, 7 LAWRENCE LANE, E.C.
1890.

Sci 621.5
Scientific

1870, Sep. 12 - 1873, Nov. 24.

LONDON :

PRINTED BY WILLIAMS AND STRAHAN,

7 LAWRENCE LANE, CHEAPSIDE.

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ERRATUM IN VOL. XV.

Page 234, Table IV. For Mean Temperature between Latitudes 53° and 54° , read $47^{\circ}\cdot 5$, instead of $46^{\circ}\cdot 5$.

16-17
1890-91
12 12

Quarterly Journal
OF THE
**ROYAL
METEOROLOGICAL
SOCIETY.**

EDITED BY A
COMMITTEE OF THE COUNCIL.

JANUARY 1890.
VOL. XVI. No. 73.

LONDON:
EDWARD STANFORD, 26 & 27 COCKSPUR ST., CHARING CROSS, S.W.;
WILLIAMS AND STRAHAN, 7 LAWRENCE LANE, CHEAPSIDE, E.C.

Price Five Shillings.

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Royal Meteorological Society.

ESTABLISHED 1850. INCORPORATED BY ROYAL CHARTER, 1866.

OFFICE:—30 GREAT GEORGE STREET, WESTMINSTER, S.W.

SESSION 1890.

ORDINARY MEETINGS at 7 p.m.

JANUARY	15	|	MAY	21
FEBRUARY	19	|	JUNE	18
MARCH	19	|	NOVEMBER	19
APRIL	16	|	DECEMBER	17

ANNUAL GENERAL MEETING.—JANUARY 15.

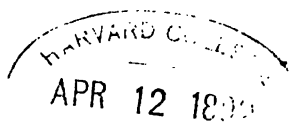
EXHIBITION OF INSTRUMENTS.—MARCH 18 to 21.

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QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY.

VOL. XVI.

JANUARY 1890.

No. 78.

SECOND REPORT OF THE THUNDERSTORM COMMITTEE.

Distribution of Thunderstorms over England and Wales, 1871-1887.

By WILLIAM MARRIOTT, F.R.Met.Soc., Assistant Secretary.

[Read November 20th, 1889.]

In 1888 the Royal Meteorological Society commenced the collection of systematic observations of Thunderstorms over England and Wales. A large mass of valuable information has already been obtained, which is now being tabulated and plotted on maps ready for discussion. This will afford data for ascertaining the monthly and hourly frequency of thunderstorms, and also for tracing their path across the country.

Some four or five years ago I commenced extracting from *Symons' British Rainfall* and from the Registrar-General's *Quarterly Returns of Births and Deaths* all the dates on which thunderstorms were reported to have occurred at any station in the British Isles. Other duties, however, prevented me from continuing and completing the work. On the appointment of the Thunderstorm Committee, I placed before them the information which I had collected. The Committee considered it desirable that this work for England and Wales should be extended and completed up to the end of 1887. This has now been done, and the results are now submitted.

NEW SERIES.—VOL. XVI.

A

All the returns from the Society's Second Order and Climatological Stations have been carefully examined, and the dates of the occurrences of thunderstorms extracted. These stations from about 1877 have furnished valuable data, which have formed a good working basis; and with these have been incorporated the dates extracted from the *Observations from Stations of the Second Order* published by the Meteorological Office.

In this investigation only the number of days on which thunderstorms occurred have been dealt with. All notices of thunderstorms, thunder without lightning, lightning without thunder, and sheet, or distant, lightning, have been grouped together as "thunderstorms."

The stations have been arranged according to the Divisions adopted by the Registrar-General of Births and Deaths, the same arrangement as is employed in *Symons' British Rainfall*. There are eleven Divisions, which contain the following Counties :—

DIVISION.	COUNTIES.
I. Middlesex.	
II. Surrey, Kent, Sussex, Hampshire, Berks.	
III. Herts, Buckingham, Oxford, Northampton, Huntingdon, Bedford, Cambridge.	
IV. Essex, Suffolk, Norfolk.	
V. Wilts, Dorset, Devon, Cornwall, Somerset.	
VI. Gloucester, Hereford, Shropshire, Stafford, Worcester, Warwick.	
VII. Leicester, Rutland, Lincoln, Notts, Derby.	
VIII. Cheshire, Lancashire.	
IX. Yorkshire.	
X. Durham, Northumberland, Cumberland, Westmoreland.	
XI. Monmouth, and Wales.	

It will be seen that the Divisions are not by any means of the same size, No. I. consisting only of the small county of Middlesex, while II. and V. together comprise the whole of the South of England. It must be borne in mind that although some of the Divisions may be large, the population is sparse, and consequently there is a great lack of observers. On the whole, however, there has been a fair distribution of stations, the yearly average number of reporting stations for the 17 years being 148, which were distributed as follows :—

Divisions	...	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
No. of stations		6	26	10	11	27	18	18	8	9	10	10

Tables I. to XI. give the monthly and yearly number of days on which thunderstorms or sheet lightning were recorded in each Division during the 17 years, 1871-1887.

The yearly distribution is shown graphically in Fig. 1. The years of greatest frequency were 1880, 1882, 1884, and 1872; and the years of least frequency, 1887, 1874, 1879, and 1871. The most striking feature in

this diagram is the see-saw nature of the curves, years of greater or less frequency alternating regularly throughout nearly the whole of the period.

The average yearly number of thunderstorms is about 89. The Divisions with the greatest yearly frequency are II. with 58.4, V. with 52.8, and X. with 50.1. The Divisions with the least yearly frequency are I. with 17.9, VIII. with 28.6, and IX. with 32.7. (Fig. 8.)

The monthly distribution is shown graphically in Fig. 2. The month

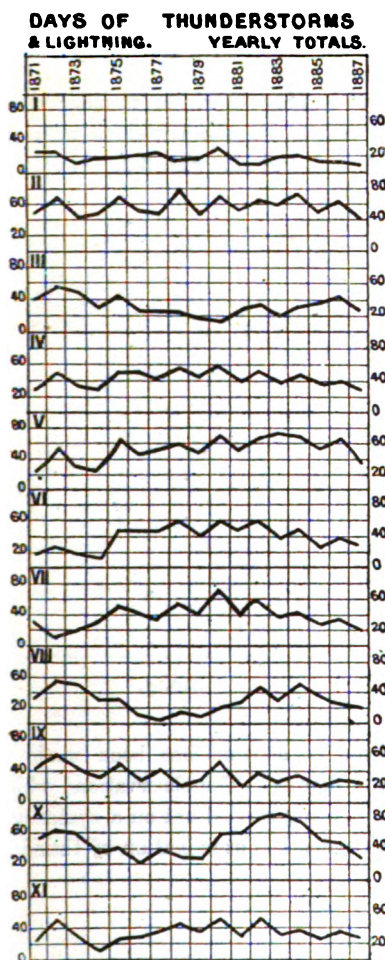


FIG. 1.

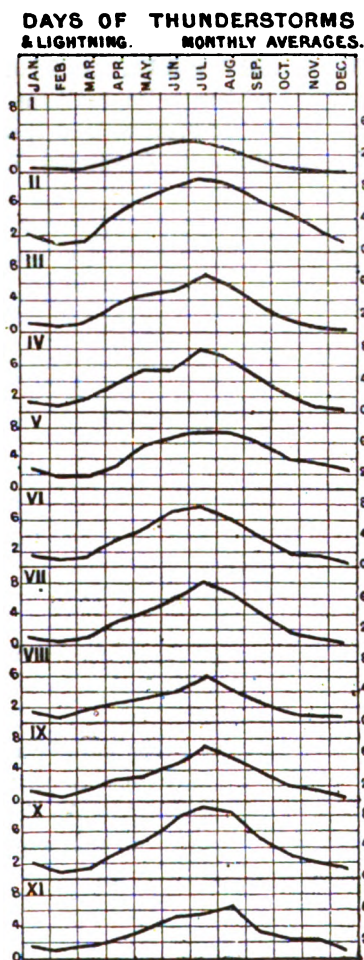


FIG. 2.

with the greatest number of thunderstorms in all Divisions is July, except in Division XI. when it is August. The months with the least number of thunderstorms are February and December. The former month is, however, shorter than the latter by 8 days.

By dividing the year into two halves, viz. April to September, and

October to March, we get the frequency of summer and winter thunderstorms respectively. The figures are as follows:—

Division.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
Summer ...	15·9	48·7	28·8	34·1	36·0	32·3	31·9	21·9	26·0	39·0	24·6
Winter.....	2·0	14·7	6·1	7·9	16·3	7·2	5·9	6·7	6·7	11·1	8·9

The Divisions which have the greatest number of summer thunderstorms are II. with 48·7, X. with 39·0, V. with 36·0, and IV. with 34·1; the Divisions which have the least number are I. with 15·9, VIII. with 21·9, XI. with 24·6, and IX. with 26·0.

The Divisions which have the greatest number of winter thunderstorms are V. with 16·3, II. with 14·7, and X. with 11·1; the Divisions with the least number being I. with 2·0, VII. with 5·9, and III. with 6·1. (Fig. 4.)

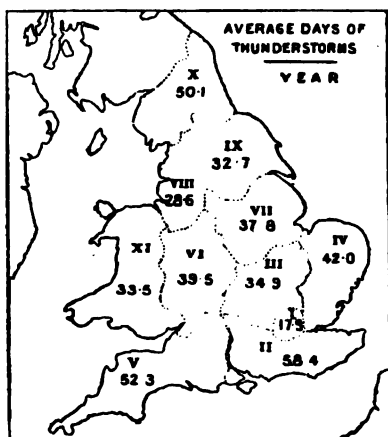


FIG. 3.

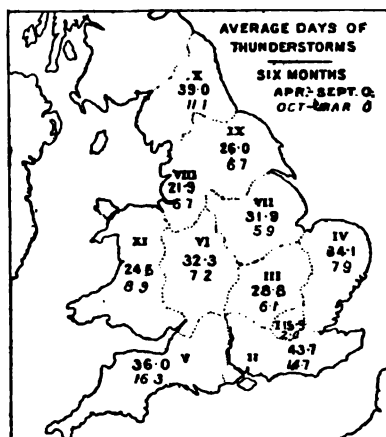


FIG. 4.

This Report being entirely statistical, no attempt has been made to generalise or draw conclusions from the figures. The observations which are now being collected by the Society are being carried out on a systematic plan, and will afford data for a much more detailed examination of thunderstorm phenomena.

TABLE I.

DIVISION I.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871-1887.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1871	..	..	1	5	3	9	3	2	1	1	..	..	25
1872	..	1	..	1	3	5	10	3	2	1	..	..	26
1873	1	..	..	2	2	2	..	2	1	1	..	..	11
1874	..	..	..	1	5	3	4	2	1	..	..	..	16
1875	..	..	..	..	1	6	2	3	4	2	..	..	18
1876	..	..	..	3	..	2	3	4	7	2	..	..	21
1877	..	..	2	3	6	5	4	4	..	..	1	..	25
1878	..	..	..	..	3	3	2	6	..	..	..	..	14
1879	..	..	2	1	3	2	3	4	1	..	..	1	17
1880	..	2	..	3	2	5	12	4	2	2	..	..	32
1881	..	..	..	1	3	1	3	1	1	..	..	..	10
1882	..	..	..	..	1	3	2	2	1	2	..	..	11
1883	..	..	..	..	1	6	9	1	1	..	1	..	19
1884	3	2	..	3	2	3	3	4	2	..	..	..	22
1885	1	..	..	..	4	..	1	5	3	1	..	..	15
1886	..	..	1	1	3	2	2	..	1	2	..	1	13
1887	..	..	1	..	2	..	2	5	..	..	..	..	10
Totals	5	5	7	24	44	57	65	52	28	14	2	2	305

TABLE II.

DIVISION II.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871-1887.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1871	2	..	..	5	5	8	11	7	4	5	1	..	48
1872	4	1	5	4	6	7	11	8	5	10	7	2	70
1873	8	..	2	4	2	3	6	5	4	6	3	..	43
1874	1	1	1	2	7	5	9	8	10	2	2	3	51
1875	4	1	..	..	9	13	7	13	12	8	4	..	71
1876	..	..	6	4	1	10	8	8	9	5	2	2	55
1877	1	1	3	8	2	7	8	8	2	4	6	..	50
1878	1	1	..	7	15	12	6	18	5	8	6	..	79
1879	..	2	..	5	6	7	9	10	5	2	..	2	48
1880	1	1	1	6	8	10	17	11	7	4	5	1	72
1881	..	2	..	3	8	9	9	6	7	1	5	2	52
1882	1	..	4	6	8	9	7	6	9	13	3	..	66
1883	2	..	..	2	5	16	12	4	7	3	7	1	59
1884	3	4	1	5	8	9	16	14	6	5	..	5	76
1885	1	1	..	3	13	4	4	7	10	5	..	1	49
1886	3	..	1	9	11	8	9	3	5	9	2	4	64
1887	..	..	..	..	4	..	8	10	7	3	4	4	40
Totals	32	15	24	73	118	137	157	146	114	93	57	27	993

TABLE III.

DIVISION III.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871-1887.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1871	..	1	2	5	3	4	10	10	4	1	..	..	40
1872	2	1	2	6	5	10	12	4	7	2	6	..	57
1873	4	..	2	3	5	4	10	9	4	6	1	..	48
1874	..	..	..	1	5	4	9	4	4	..	..	..	27
1875	4	..	1	..	5	10	9	7	5	5	..	1	47
1876	..	..	2	2	..	2	4	7	7	2	..	..	26
1877	1	..	2	5	5	2	4	5	1	1	..	..	26
1878	..	..	..	2	6	6	2	7	2	..	..	..	25
1879	..	..	2	2	3	4	..	4	2	..	..	..	17
1880	..	2	2	7	2	7	15	6	6	5	1	2	55
1881	..	2	3	3	3	5	3	4	2	..	1	1	27
1882	..	..	..	4	5	9	11	1	3	2	1	..	36
1883	..	..	..	..	2	10	6	1	1	..	..	..	20
1884	1	2	1	2	5	3	7	5	2	1	..	3	32
1885	..	3	1	4	10	1	3	8	5	2	..	..	37
1886	1	..	..	7	7	4	8	5	3	7	1	3	46
1887	..	..	2	..	3	2	7	8	3	1	2	..	28
Totals	13	11	22	53	74	87	120	95	61	35	13	10	594

TABLE IV.

DIVISION IV.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871-1887.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1871	1	1	1	7	1	1	7	2	3	2	2	..	28
1872	1	3	2	4	6	1	11	9	8	4	..	..	49
1873	6	..	2	2	4	3	2	7	3	2	..	..	31
1874	2	..	..	..	1	4	9	3	5	1	1	1	27
1875	2	..	2	..	7	12	9	6	8	2	2	..	50
1876	..	5	5	6	3	4	8	9	6	3	..	..	49
1877	5	1	4	6	4	5	7	8	2	..	1	..	43
1878	1	..	..	3	14	7	5	15	4	6	2	..	57
1879	..	..	3	4	6	11	5	10	4	1	..	..	44
1880	..	2	4	6	3	7	19	8	8	..	1	1	59
1881	..	1	..	2	7	4	8	8	5	..	2	..	37
1882	..	..	..	5	3	13	12	9	1	5	2	..	50
1883	..	..	..	1	5	10	10	3	2	3	3	2	39
1884	3	2	..	6	5	3	13	6	5	2	..	2	47
1885	..	..	..	1	13	2	2	6	7	4	..	1	36
1886	1	..	2	4	7	4	6	3	3	7	..	2	39
1887	..	..	2	1	3	2	7	6	5	2	..	1	29
Totals	22	15	27	58	92	93	140	118	79	44	16	10	714

TABLE V.

DIVISION V.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871-1887.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1871	..	..	1	1	1	1	2	7	4	5	1	..	23
1872	6	1	1	1	7	7	8	7	6	3	6	3	56
1873	5	1	3	1	2	4	4	3	1	4	4	..	32
1874	1	1	2	1	7	3	3	2	5	1	..	..	26
1875	7	4	1	1	5	11	4	14	10	3	5	1	66
1876	..	2	7	2	3	2	3	9	9	3	2	4	46
1877	6	1	4	7	3	5	4	8	1	3	7	2	51
1878	2	..	..	..	11	11	7	12	8	4	2	2	59
1879	..	2	..	5	7	11	7	9	2	1	1	2	47
1880	..	2	1	4	5	7	21	9	6	5	3	6	69
1881	..	3	..	1	5	7	10	8	8	1	6	4	53
1882	2	..	..	8	7	9	14	4	5	8	7	3	67
1883	3	3	2	1	8	15	15	4	9	3	10	..	73
1884	4	6	2	2	5	9	13	9	7	4	1	6	68
1885	2	2	1	1	9	6	1	9	10	8	..	3	52
1886	6	..	3	12	4	4	4	5	8	9	2	9	66
1887	..	..	..	3	5	1	4	5	5	3	6	3	35
Totals	44	28	28	51	94	113	124	124	104	68	63	48	889

TABLE VI.

DIVISION VI.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871-1887.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1871	..	..	..	2	..	4	2	6	3	1	..	..	18
1872	..	..	..	1	3	7	7	5	4	1	2	..	30
1873	4	..	2	3	..	3	3	3	..	..	1	..	19
1874	..	..	..	..	2	2	6	..	1	..	2	..	13
1875	7	..	..	..	4	10	12	5	5	3	1	1	48
1876	1	4	5	5	3	7	6	8	5	2	..	1	47
1877	..	..	1	5	10	9	7	8	3	1	3	..	47
1878	..	..	1	3	12	12	7	13	3	5	..	2	58
1879	..	..	2	4	4	13	5	8	2	2	1	..	41
1880	..	2	1	6	6	13	17	8	7	1	2	..	63
1881	..	..	3	6	6	7	8	10	2	1	6	..	49
1882	1	..	2	5	9	10	14	6	6	3	2	2	60
1883	..	1	..	..	2	10	8	4	4	2	4	1	36
1884	3	3	..	4	6	7	15	4	4	..	..	3	49
1885	1	1	..	3	5	2	..	5	6	2	1	..	26
1886	1	..	3	7	6	4	3	4	3	3	1	4	39
1887	..	..	..	2	4	1	8	5	3	4	2	..	29
Totals	18	11	20	56	82	121	128	102	61	31	28	14	672

TABLE VII.

DIVISION VII.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871-1887.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1871	..	2	2	3	1	5	9	5	1	2	..	..	30
1872	1	1	..	..	..	1	5	..	1	..	..	..	9
1873	2	..	1	3	3	4	1	1	..	1	1	..	17
1874	..	..	..	3	1	3	9	4	7	1	1	..	29
1875	3	1	..	1	8	13	9	8	5	2	2	..	52
1876	..	1	3	6	3	5	6	9	8	2	..	1	44
1877	1	1	1	4	5	4	5	8	2	1	1	..	33
1878	1	..	1	3	11	9	4	17	4	6	1	..	57
1879	..	..	2	1	6	10	9	10	2	2	..	..	42
1880	..	1	3	11	4	12	20	10	10	..	1	1	73
1881	..	..	4	3	4	3	10	6	4	..	5	..	39
1882	..	..	..	3	10	12	15	10	4	1	3	..	58
1883	..	..	..	..	4	9	10	2	3	4	2	3	37
1884	3	1	..	4	5	3	14	6	3	..	..	2	41
1885	1	1	..	2	7	1	1	5	7	2	1	..	28
1886	..	..	2	8	4	2	5	1	2	6	..	3	33
1887	..	..	2	2	2	1	5	5	2	..	1	..	20
Totals	12	9	21	57	78	97	137	107	65	30	19	10	642

TABLE VIII.

DIVISION VIII.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871-1887.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1871	..	1	6	2	1	4	9	10	1	..	3	..	37
1872	3	..	2	4	3	11	13	7	9	3	..	1	56
1873	4	..	..	3	5	7	9	8	5	6	..	..	47
1874	1	..	2	4	2	1	7	7	5	..	..	..	29
1875	2	..	..	1	4	5	4	5	5	1	1	1	29
1876	..	..	3	2	..	1	2	1	1	..	..	..	10
1877	..	..	1	..	1	..	1	3	..	..	..	..	6
1878	..	..	1	..	5	2	1	5	..	1	..	..	15
1879	..	..	1	1	..	4	1	2	..	..	..	..	9
1880	..	..	..	2	..	6	10	..	2	..	..	1	21
1881	..	..	..	1	6	3	5	3	2	1	6	..	27
1882	..	..	1	4	9	8	12	3	1	4	5	..	47
1883	1	1	2	2	2	7	5	1	1	3	1	..	26
1884	5	3	2	5	1	2	13	5	5	1	2	5	49
1885	2	3	..	3	10	1	1	4	5	3	..	2	34
1886	2	..	1	2	3	2	3	1	2	3	..	6	25
1887	..	..	1	1	..	1	4	6	4	..	..	2	19
Totals	20	8	23	37	52	65	100	71	48	26	18	18	486

TABLE IX.

DIVISION IX.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871-1887.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1871	1	1	4	5	3	3	8	10	2	2	..	1	40
1872	4	..	2	5	7	9	11	8	7	2	3	1	59
1873	4	2	..	2	5	1	8	7	6	6	1	..	42
1874	2	..	2	2	1	1	6	7	3	..	1	..	31
1875	2	1	..	3	5	11	8	8	6	1	1	2	48
1876	..	..	3	2	..	4	5	6	2	3.	..	1	26
1877	1	..	2	6	4	5	5	6	2	2	6	1	40
1878	1	..	..	..	5	3	..	5	2	2	3	..	21
1879	..	..	1	2	3	6	5	7	1	..	2	1	28
1880	..	..	..	4	1	9	12	3	3	..	..	..	32
1881	..	..	1	..	..	2	5	4	2	..	3	1	18
1882	..	..	1	2	3	9	12	1	3	1	4	..	36
1883	..	..	..	..	2	7	6	4	3	3	1	2	28
1884	3	..	..	5	1	1	13	7	4	..	..	..	34
1885	..	..	..	2	6	1	1	3	5	3	..	1	22
1886	..	1	1	2	3	..	5	3	3	7	1	1	27
1887	..	..	2	3	..	..	6	4	5	4	..	..	24
Totals	18	5	19	45	49	77	117	98	59	36	26	12	556

TABLE X.

DIVISION X.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871-1887.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1871	..	..	2	4	2	7	11	14	3	4	4	2	53
1872	1	..	1	3	6	10	14	11	8	5	3	2	64
1873	6	..	1	4	4	8	14	7	6	7	1	..	58
1874	1	..	..	3	..	5	11	6	7	..	..	..	33
1875	2	..	..	3	3	5	7	6	8	2	2	3	41
1876	..	..	1	2	1	2	4	5	2	3	..	..	20
1877	..	..	1	4	1	6	6	15	4	1	..	1	39
1878	1	1	..	..	9	8	6	6	..	..	1	..	32
1879	..	..	..	3	1	8	4	8	3	..	1	..	28
1880	1	1	1	2	1	15	14	8	9	2	3	1	58
1881	4	..	2	8	9	9	5	7	6	1	6	3	60
1882	2	2	1	6	13	14	18	8	3	6	6	2	81
1883	1	3	6	5	6	20	10	8	8	8	4	5	84
1884	6	3	3	8	8	4	17	11	7	2	3	4	76
1885	1	1	..	2	16	3	7	5	7	8	1	1	52
1886	4	2	2	..	4	4	5	9	4	7	2	5	48
1887	..	..	1	1	2	4	6	7	3	1	..	..	25
Totals	30	13	22	58	86	132	159	141	88	57	37	29	852

TABLE XI.

DIVISION XI.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871-87.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1871	..	1	3	..	2	1	5	4	..	..	1	1	18
1872	4	..	1	3	1	6	7	8	11	3	6	1	51
1873	4	..	1	3	2	4	4	5	1	3	..	..	27
1874	..	..	1	..	2	..	5	2	1	..	..	1	12
1875	2	..	..	..	..	3	4	6	6	2	..	2	25
1876	..	2	3	4	..	3	2	7	4	3	..	..	28
1877	2	1	2	1	4	3	5	6	..	3	9	..	36
1878	..	..	1	1	9	6	5	13	3	3	5	1	47
1879	..	2	..	1	..	10	2	13	3	3	..	2	36
1880	..	1	1	2	2	14	14	8	3	3	2	..	50
1881	..	..	2	1	5	5	3	5	1	..	5	2	29
1882	1	..	1	3	8	9	13	5	4	3	5	..	52
1883	1	..	2	3	3	6	5	2	3	4	3	..	32
1884	2	4	2	1	4	6	7	5	3	1	1	1	37
1885	3	2	1	1	3	3	1	7	3	2	1	1	28
1886	1	..	1	5	7	5	3	2	5	2	..	3	34
1887	..	..	..	2	3	..	4	9	2	4	1	2	27
Totals	20	13	22	31	55	84	89	107	53	39	39	17	569

TABLE XII.

MONTHLY AVERAGE NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH DIVISION, 1871-1887.

Division.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
I.	0.3	0.3	0.4	1.4	2.6	3.4	3.8	3.1	1.6	0.8	0.1	0.1	17.9
II.	1.9	0.9	1.4	4.3	6.9	8.0	9.2	8.6	6.7	5.5	3.4	1.6	58.4
III.	0.8	0.6	1.3	3.1	4.4	5.1	7.0	5.6	3.6	2.0	0.8	0.6	34.9
IV.	1.3	0.9	1.6	3.4	5.4	5.5	8.2	7.0	4.6	2.6	0.9	0.6	42.0
V.	2.6	1.6	1.6	3.0	5.5	6.6	7.4	7.4	6.1	4.0	3.7	2.8	52.3
VI.	1.1	0.7	1.2	3.3	4.8	7.1	7.5	6.0	3.6	1.8	1.6	0.8	39.5
VII.	0.7	0.5	1.2	3.4	4.6	5.7	8.1	6.3	3.8	1.8	1.1	0.6	37.8
VIII.	1.2	0.5	1.4	2.2	3.1	3.8	5.9	4.1	2.8	1.5	1.0	1.0	28.6
IX.	1.0	0.3	1.1	2.7	2.9	4.5	6.9	5.5	3.5	2.1	1.5	0.7	32.7
X.	1.8	0.8	1.3	3.4	5.0	7.8	9.3	8.3	5.2	3.3	2.2	1.7	50.1
XI.	1.2	0.8	1.3	1.8	3.2	5.0	5.2	6.3	3.1	2.3	2.3	1.0	33.5

DISCUSSION.

Mr. WHIPPLE said, that in a paper read by himself before the Society, in January 1888 (*Quarterly Journal*, Vol. XIV. p. 92), in which he had discussed the information contained in the Symbols Tables published in the *Meteorological Record*, tables would be found similar to those compiled by Mr. Marriott. The material used in his own investigation was much less copious than that which Mr. Marriott had employed, the Symbols Tables only extending from 1878 to 1885. The divisions or districts he had adopted, were those known as the Meteorological Office Districts. It was a pity that this system of districts had not been adhered to by Mr. Marriott, as some comparison between his own results and those contained in the present report could have then been made, but the

adoption of the Registrar General's Divisions made any comparison impossible. He considered it would have been better, in a small territory like the British Isles, if thunderstorms had been treated separately, and occurrences of sheet lightning and distant thunder kept distinct. The occurrence of sheet lightning in a particular district did not necessarily involve that a thunderstorm was experienced there, for it frequently happened that the storm was a long way off. He remembered Mr. Symons quoting an instance in which the reflected lightning of a thunderstorm in progress in the English Channel near the French coast was seen as far distant as the more northern of the Midland counties. He was sorry that so much labour had been devoted to this investigation, and no distinction made between thunderstorms and sheet lightning.

Mr. BRODIE regretted that Mr. Marriott should have adopted for meteorological purposes the districts selected for entirely different uses by the Registrar General. The divisions were doubtless chosen originally with a view to securing a fairly equal distribution of population. The result of the present investigation seemed to show that, the larger the district, the greater number of days with thunderstorms; and the values for the different divisions were therefore in no way comparable. He was also sorry that sheet lightning had been included under the head of thunderstorms, the former being often observed when there was no thunder at all in the neighbourhood.

Mr. SCOTT remarked, in reference to Mr. Brodie's observation regarding sheet lightning, that in his opinion sheet lightning was always the reflection of an ordinary flash, as he did not know what other electrical discharges could occur. A discussion on the subject had taken place at the Vienna Congress, the outcome of which, however, had not been quite in accordance with his (Mr. Scott's) views.

Mr. BUCHAN considered that results had been obtained from Mr. Marriott's discussion which no future observations would alter. The maps clearly indicated the parts of the country subject to winter thunderstorms, and the curves made it plain that July and August were the months of greatest frequency of thunderstorms, there being no decided increase until after the summer solstice. The only true way of discussing such observations was by taking results from individual stations. Regarding the difference of opinion concerning the divisions adopted, it appeared that the Meteorological Office divided the country for one purpose and the Registrar General for another, and it became our duty to discover the best way of dividing the country for the purpose of meteorological investigations. He believed that all distant thunder should be included with thunderstorms, as thunder could not be heard at any great distance, but the inclusion of sheet lightning under the head of thunderstorms was certainly unadvisable, as he was of opinion that 80 per cent. of sheet lightning was unaccompanied by thunder. He then referred to the results of an examination he had made of the observations of lightning at Oxford, and made some remarks concerning the diurnal variation of thunderstorms at this place and on the discordance of the facts deduced from observation with the theories of electricians.

Dr. TRIPE said that the investigation of thunderstorm phenomena was in its infancy, and even the following of wrong methods was not without its use, for it served to show what should be done. The curves clearly illustrated the fact that July was the month of maximum days of thunderstorms in all districts except in Wales, where the maximum occurred in August, and it was possible that the mountainous character of the Welsh districts might have something to do with bringing about this difference. There was no doubt that Middlesex was much too small a division to be compared with the others. The observations collected might, however, be transferred to Divisions Nos. 2 or 3. The number of years discussed rendered the observations more valuable than if a shorter period had been taken, such as that during which our own climatological stations had been at work.

Mr. SYMONS said that he had no idea that the question of divisions would be brought forward, and he was not prepared to discuss there and then the merits of either the Meteorological Office districts or the Registrar General's divisions; but it must be remembered that the former were of comparatively recent formation, whereas the latter date from 1839. As regarded the paper itself, he agreed with the remarks which had been made by Mr. Buchan, with the exception of the one concerning the occurrence of sheet lightning at Oxford. He should much like to know if any special means were taken to watch the weather continuously

from say 6 or 7 p.m., when the staff would probably have ceased routine duties for the day until the next morning, otherwise the increase of recorded occurrences of lightning between 8 and 9 p.m. was possibly due to the fact that the evening observations were taken about these hours, so that conditions would then be favourable for the observation of electrical phenomena. He was sorry sheet lightning had been included under the head of thunderstorms, as lightning was frequently visible over a very large area.

Mr. BUCHAN remarked that he had examined the records of 180 places distributed over the globe in order to ascertain the diurnal variation of the occurrence of thunderstorms, and had found the results obtained corroborated those deduced from the Oxford observations.

Mr. GLYDE remarked that sheet lightning must often occur in the day time, but the light prevented it from being seen. Regarding the distance at which thunder could be heard, he said that he remembered hearing thunder on one occasion, which, according to the ordinary method of calculation, was at least 22 miles distant.

Mr. MAWLEY remarked that if Mr. Marriott's treatment of the observations was as mistaken as it had been said to be, it seemed to him a curious coincidence that the curves for the different districts should support each other so remarkably well as they did in both diagrams.

• On the CHANGE OF MEAN DAILY TEMPERATURE WHICH ACCOMPANIES THUNDERSTORMS IN SOUTHERN ENGLAND.

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Superintendent of the Kew Observatory of the Royal Society.

[Received October 15th.—Read November 20th, 1889.]

THIS brief communication is submitted to the Royal Meteorological Society as the result of a somewhat cursory examination of the records of the Kew Observatory for the past ten years, 1879 to 1888 inclusive, with the view of investigating the effects of thunderstorms on the local mean daily temperature.

It is very generally quoted as a weather proverb that English climate in summer is made up of sequences of, first three hot days and then a thunderstorm. There is also a widely-spread belief that thunderstorms cool the air. Both these statements now appear to be in great measure fallacious.

Without in any way classifying the storms, either according to season, to their being cyclonic or anticyclonic, line storms or otherwise, the author has taken the Observatory MS. Journals and extracted the dates of the actual storms of thunder and lightning which directly passed over the Kew Observatory, omitting all those cases where the entries were merely those of 'distant thunder,' 'sheet lightning,' or of 'thundery-looking clouds observed.'

This done, the mean temperatures for differences were then taken, and

Table I. formed, in which the following values are given :—In column 1, the date of the thunderstorm ; column 2, the amount of change of mean temperature between that day and the day preceding ; column 3, the similar change between the mean temperature of the two days prior to and the two days subsequent to the storm ; finally, column 4 shows the similar amount of change between the mean of three days before and the mean of the three days after its occurrence.

TABLE I.
CHANGE OF TEMPERATURE ACCOMPANYING THUNDERSTORMS.

Date.	Change.			Date.	Change.		
	In 1 day.	In 2 days.	In 3 days.		In 1 day.	In 2 days.	In 3 days.
1879. May 14....	—2°	—3°	—1°	1884. June 29....	—5°	—2°	—1°
" 28....	+1	+2	+1	July 6....	—4	0	—1
June 24....	0	—2	0	" 24....	—6	—9	—7
July 2....	—1	—2	—2	1885. Jan. 31....	—4	—2	—4
Aug. 2....	—2	—1	—3	May 16....	—1	—1	0
Dec. 30....	—6	+3	+7	Aug. 6-7 ..	0	+3	+3
1880. April 6-8 ..	—1	—5	—6	" 20....	+2	0	—3
July 1....	—3	—4	—4	1886. April 22....	—1	0	+3
" 15....	0	+2	+2	May 22, 23	+1	—4	—2
" 21....	+1	—1	—1	June 1....	+3	0	0
Sept. 13....	—3	—5	—6	July 25....	+1	—4	—5
1881. May 28....	+1	—1	+1	Sept. 4....	+4	+3	0
June 6....	—4	—13	—14	1887. May 3....	+5	+4	+4
July 5-6 ..	—4	—13	—11	" 21....	—4	—1	0
1882. June 9	—3	—2	—4	Aug. 17....	—2	—3	—1
1883. June 9....	+1	+1	+2	1888. March 14 ..	+8	+1	—3
" 29, 30	+7	+8	+11	April 18-19	—4	—5	—3
July 3....	—1	—7	—6	June 25....	+7	—2	—1
" 14-15	—6	—3	—4	" 28....	—2	—6	—9
Aug. 8....	—4	—4	—4	July 5-6 ..	0	—4	—2
1884. Feb. 11....	—1	+3	+4	" 16-18	+4	+2	+2
April 3....	—2	—3	—1	" 22....	+4	0	—1
" 27....	0	+2	+3	" 30....	+1	—4	—4
May 5....	—4	0	+1	Aug. 30....	0	—1	—1

In all cases a rise of temperature in the interval is indicated by + and a fall by —. The result derived from the discussion of 48 storms in the 10 years is found to be as follows :—

TABLE II.

Aggregate Change of Temperature in			
	1 Day.	2 Days.	3 Days.
Rise	+51°	+35°	+44°
Fall	—80	—117	—115
Difference	—29	—82	—71
Mean	—0°·6	—1°·7	—1°·5

We have, then, as the general effect of a thunderstorm a reduction of mean temperature of the air of 0°·6 on the day on which it occurs, of 1°·7 two days, and of 1°·5 three days afterwards.

The above figures represent the actual lowering of temperature in the mean, but in order to show how far these facts may be expected to obtain we have prepared the following table:—

TABLE III.

Number of Cases when the				
	1 Day.	2 Days.	3 Days.	Total.
Temperature rose	16	12	13	41
„ fell	19	30	30	79
„ was constant	11	6	5	22

It may, therefore, finally be concluded that a thunderstorm is accompanied by

A rise of temperature in 29 per cent. of instances

A fall „ 56 „ „

Does not affect the mean 15 „ „

and that, therefore, the proverbs respecting the supposed influence of these electrical phenomena upon the general temperature of the air in the South of England are hardly borne out by the facts, but must be relegated to the lunar influence class of popular sayings.

Incidentally it may be noted that the average number of thunderstorms passing annually over the Kew Observatory is 4·8. In the paper read before the Society in January, 1888, the author, in discussing the weather of England and Wales for the period 1878-1885, obtained 4 as the mean number of thunderstorms annually observed in District V. or Southern England. The difference of 0·8 is probably due to the exceptionally large number in 1888 which increased the average by that amount.

(The observations have been extracted from the register by permission of the Meteorological Council.)

DISCUSSION.

Mr. BLANFORD said that, as he understood the author's account of it, the paper did not clearly show whether, and to what extent, thunderstorms had a cooling effect on the atmosphere. Thunderstorms usually occur in the late hours of the afternoon, and in taking the mean temperature of the day the high temperature of the hours preceding the storm is in a great measure neutralised by the coolness that follows. He knew, from experience, that in the Tropics the effect of a thunderstorm upon the temperature of the air is very great, and he had seen the temperature fall 20° in as many minutes on the approach of a storm. The method of comparison of mean temperatures followed by Mr. Whipple did not seem suited to the inquiry, for in order to ascertain the cooling effect of a thunderstorm it would surely be most correct to compare the temperature shortly before the thunderstorm with that registered shortly after the storm had passed, after allowing for the normal diurnal fall of temperature, according to the hour of the day.

Mr. CURTIS remarked that in immediate connection with thunderstorms large sudden falls of temperature were frequently recorded by thermographs, and at Kew such falls had been registered which were as large as those described by

¹ *Quarterly Journal*, Vol. XIV. p. 92.

Mr. Blanford. With regard to the method Mr. Whipple had adopted for making his comparison, he considered it was open to grave objection, as it was liable to mask such changes as really did occur.

Mr. BUCHAN described some investigations he had made into thunderstorms experienced in Scotland, mentioning one case in particular in which the rainfall was terrifically heavy over an extremely small area, and stated that he had found that these storms were really very small cyclonic centres, sometimes only amounting to a barometric depression of two or three hundredths of an inch. He had noticed that when the relation between the direction of the wind and the isobaric lines was irregular over a limited area, these thunderstorms should be looked for.

Mr. HUTCHINS said that his experience in Cape Colony certainly seemed to bear out the assertion that after three oppressive hot days a thunderstorm might be expected, followed by a decidedly cooler atmosphere. He had had charge of a thermograph in an eastern part of the Colony, and had often registered temperatures of 100° to 105° , and had seen this temperature reduced to 80° or 75° on the occurrence of a thunderstorm.

Mr. WHIPPLE, in reply, said that the purport of his inquiry had been entirely misunderstood. His results had no connection with temperature changes on the day of the thunderstorm, and the object was really to investigate the truth of the popular idea that after three hot days a thunderstorm would follow, after which the temperature would be cooled down. He had done this, and was now able by means of the figures he had obtained to satisfactorily answer any enquiries or remarks having reference to this generally accepted idea. The figures proved that this notion was hardly correct, for the day's temperature was never lowered more than a couple of degrees, sometimes the decrease only amounted to half a degree, and very frequently there was no decrease whatever. He was perfectly aware that the temperature frequently fell 15° or 20° when a heavy thunderstorm or hailstorm occurred, for in his long experience with thermograms at Kew Observatory he had repeated opportunities of observing such sudden changes in the curves, but with this change of temperature he was not dealing in his paper.

NOTE ON AN APPEARANCE OF ST. ELMO'S FIRE

Seen during a Thunderstorm at Walton-on-the-Naze, on September 3rd, 1889.

By W. H. DINES, B.A., F.R.Met.Soc.

[Received October 8th.—Read November 20th, 1889.]

DURING the thunderstorm of September 2nd and 3rd, a decided glow was apparent at times upon the metal cross of the Congregational Church, opposite to which I happened to be staying. The cross in question is about 8 ft. above the roof, and 40 ft. to 50 ft. from the ground, and the light seen upon it was similar, both in appearance and intensity, to that of the planet Venus when seen through a slight haze.

Lightning was very frequent throughout the night, but although often within two miles distance, it was not very vivid before 2.30 a.m. on the 3rd. About 3 a.m. it became evident that a very severe storm was occurring a few miles to the southward, and about the same time the light on the cross was first noticed. It appeared perfectly steady and unaffected by the lightning, five

or six flashes of which often occurred within the minute. As the storm came overhead, the light disappeared, or at least could not be seen. I feel certain it really disappeared, but the lightning was so frequent and vivid that it was very difficult to see anything at all between the flashes. As the storm became less severe the light reappeared, but was extinguished for a few seconds by each flash. This continued until daylight, when the phenomenon became invisible.

The metal cross was not an especially prominent point, but it was the only prominent point visible from the window from which I watched the storm. There was no lightning conductor on the chapel, but it was raining hard most of the night, so that there would be fairly good electrical communication with the ground.

Unfortunately, I left Walton early on the morning of the 8rd, and was unable to learn whether any similar appearance had been seen in other parts of the town, or whether much damage had been done by the storm.

NOTES ON CIRRUS FORMATION.

By H. HELM CLAYTON, of the Blue Hill Observatory, Mass., U.S.A.

(Communicated by A. LAWRENCE ROTCH, B.Sc., F.R.Met.Soc.)

(Plate I.)

[Received November 4th—Read November 20th, 1889.]

THE following is extracted from the notes and drawings made by the writer, who during the last few years has made a special study of cloud forms and their changes. These notes and drawings were made immediately after the observations, and sometimes after intently watching the slow changes of certain cloud forms for several hours. The observations were all made at the Blue Hill Observatory, unless stated to have been made elsewhere.

Notes on the formation of Cirrus in a previously cloudless sky.

On July 2nd, 1888, at 1 p.m., the sky was almost cloudless when cirrus began to appear on the west horizon, and although moving from the north, rapidly extended toward the zenith. At 3 p.m. the cirrus were apparently forming directly overhead. At this time there were some broad cirro-stratus bands in the west extending from 190° azimuth, or almost exactly from north, and diverging from the nearer one of these were a series of cirrus bands radiating from 140° azimuth, or from north-west and extending toward the zenith. These latter were closely watched between 3 and 4 p.m., and new bands and fibres were distinctly seen to form directly overhead. Cirrus fibres would suddenly form at certain points, generally a little east of the eastern end of existing bands, and appear as thin, barely visible, hazy forms, which would rapidly increase in extent and density; while at other

points the cirrus fibres were undergoing no change or were perhaps slowly dissolving. When the observations were begun the ends of the cirrus bands scarcely reached the zenith, but by 4 p.m. the bands extended far beyond the zenith toward the east, although they were moving from slightly east of north. While these formations were going on there were evidently two different currents near together in the upper air, moving with different velocities and in a slightly different direction. At 8 p.m. one portion of cirrus was found moving from 185° with a relative velocity of 8 on the scale used at Blue Hill Observatory; while soon after another portion was found moving from 191° with a relative velocity of 11. Also certain portions of the cirrus were seen to approach others, indicating difference of velocity. About 8.10 to 8.20 p.m. a short, broad band of cirrus, radiating from 190° , formed overhead, and the cirrus fibres in this were apparently those moving with the relative velocity of 11. This band very quickly moved off to the south and disappeared. The cirrus fibres which were formed radiated mainly from the same direction as the bands near the zenith, namely from 140° azimuth. They were not straight, however, but generally somewhat curved or curled, with the ends pointing toward the west. Between 8.30 and 8.50 p.m. there were several varieties of cirrus, namely straight cirrus fibres, cirrus plumes (Plate I., Fig. I. a), and cirrus with central bands and fibres diverging at right angles (Fig. I. b). The eastern ends of many of the bands were bent toward the south, or in the direction toward which the cirrus were moving. These phenomena seemed to indicate that a rapidly moving current was pushing under another current, and at the plane where the two currents came in contact the air was thrown into little eddies and streams, which at the same time were slowly elevated, and had their moisture condensed into cirrus fibres. Cirrus were observed to form overhead in a somewhat similar manner between 3 and 6 p.m. of April 19th, 1889. Cirrus fibres were also seen to form in a previously cloudless sky at Murfreesboro', Tenn., in the summer of 1888. On this occasion the early morning was cloudless. About 8 a.m. cumuli began to form, and about 9 a.m. a few cirrus fibres appeared near the zenith. These were closely watched, and around them new fibres were seen to be forming, elongating, and interlacing with previously formed fibres, until within a few hours the sky was covered with a network of cirrus.

The formation of Cirrus bands with cross fibres.

The writer has also observed the formation of cirrus bands in a previously nearly cloudless sky. On March 31st, 1887, at 2 p.m., cirrus was seen to be forming in the south-west, with the area of formation extending toward the zenith. Between 2 and 3 p.m. the process was closely watched near the zenith, and it was seen that short parallel fibres would first appear (Fig. II. a), and then fibres would cross them (Fig. II. b). The formation was accompanied by an increase in the relative velocity of the cirrus, and the shorter bands near the zenith were moving from a slightly different direction to the movement of the bands near the horizon. An almost exactly similar process of cloud

formation was observed near the zenith on March 25th, 1888, at 8 a.m. On February 28rd, 1887, at 11 a.m., cirrus were observed which consisted of straight fibres arranged parallel to one another so as to form long bands (Fig. II. c). Some of these had cross fibres extending in the direction of the larger axis of the bands; and these were found to be moving in the same direction, but with only about half the velocity of the other fibres, though both were moving with unusual rapidity. Soon after 11 a.m. nearly all of the fibres assumed the direction of the longer axis of the bands, namely from azimuth of 115° , or nearly North-west. At 8 p.m. these were again noticed to be crossed by short transverse fibres, which appeared to be moving in the same direction and with the same velocity.

On December 11th, 1886, a band with cross fibres was observed (Fig. II. d). On this occasion, the cross fibres were found to be moving from a direction slightly different to that of the fibres extending in the direction of the long axis of the band, and this was thought to be their cause.

The formation of Cirrus from cirro-cumulus clouds.

The formation of cirrus from clouds of the cirro-cumulus or cumulo-cirrus type has been repeatedly observed. The following are some forms observed (Fig. III., a, b, c, d, e, f):—

These forms apparently all resulted from descending clouds. The heavy particles fell fastest and succeeded one another on account of the less resistance, and thus formed long fibres which were usually carried backward from the cloud on account of the decrease of wind velocity with lower altitude; but in the form "a," which was observed at Murfreesboro', Tenn., during the summer of 1882 the fibres hung almost perpendicularly under the cloud. The appearance was the same in all parts of the sky, and evidently not due to perspective. On watching these clouds it is seen that the fibres continuously move outward from the clouds until the entire cloud is drawn out into pure cirrus. In the form "f," which was observed August 16th, 1889, the fibres on one side were visibly lower than the cloud, while on the other they were visibly higher. In this case, the cloud was evidently descending into a more rapidly moving current. The lower portions were carried in advance of the cloud, while the upper portions were retarded and drawn out into fibres in the rear of the cloud, so that the cloud assumed the appearance of what has been called "cat's-tail cirrus."

Cirrus drawn out from cumulus clouds.

Several times cirrus has been observed to elongate outward from the top of cirro-cumulus clouds, being apparently drawn outward by a more rapid current at the top than at the base of the cirro-cumulus. The following was observed on July 8rd, 1888, and a similar formation of cirrus from the tops of bands of cirro-cumulus has been observed on several previous occasions (Fig. III. g):—

From the top of almost every well-developed shower cloud cirrus fibres may be seen extending. The writer has also repeatedly seen cirrus fibres drawn out from small cumulus clouds. Such clouds were observed on

January 1st and April 16th, 1888, February 18th and 28rd, 1889; and at Ann Arbor, Mich., once in February, and once in April, 1885. On most of these occasions the temperature was low, being near and sometimes below zero Fahr., and this was thought to be the reason why the difference of wind velocity in different portions of the cloud could draw the cloud matter out into long fibres before dissolving by evaporation.

Notes on the formation of "mare's-tail" cirrus.

By "mare's-tail" cirrus are meant those which have curved forms (Fig. IV.). On April 12th, 1888, from 7 to 9 a.m., the relative velocity of the cirrus increased from 8 to 18 on the scale used at Blue Hill Observatory, and at 9 a.m. it was noticed that the front ends of all the cirrus bands were bent backward. This suggested that the cause of curved "mare's-tail" cirrus was that the current in which the cloud floated moved with a greater velocity than the air immediately in front of it, and as it came in contact with this air was deflected to one side and thus distorted the clouds, giving them a curved appearance. This conclusion appears to have been fully confirmed by subsequent observations. On May 8rd, 1888, the cirrus slightly increased in velocity between 5 and 6 p.m., and at 6 p.m. the front of the cirrus fibres were bent backward. On May 20th, at 7 a.m., the cirrus were curved backward and were evidently increasing in velocity. The relative velocity measured at 7 a.m. was found to be 10; at 7.5 a.m., 12; at 7.15 a.m., 16; and at 7.20 a.m., 17. On May 22nd the cirrus were found alternately curved backward and forward at short intervals of time. No perceptible changes in velocity were measured. On May 24th, between 8 and 9 a.m., the relative velocity of the cirrus increased from 5 to 8. At 8.30 a.m. the front of the cirrus fibres were curved backward. On June 3rd, at 6 p.m., the rear ends of the cirrus were curved forward, and it was found that the cirrus were slowly decreasing in velocity. On June 18th, at 8.30 p.m., cirrus in the east were curved forward, while cirrus in the west were curved backward. At 4 p.m. it was found that cirrus in the east were moving with a relative velocity of 4, while cirrus in the west were moving with a relative velocity of 7.

A number of observations similar to the foregoing have been made.

These curved cirrus, when accompanied by decreasing barometric pressure, frequently indicate that a storm of increasing energy is approaching.

DISCUSSION.

THE PRESIDENT (Dr. MARCET), after remarking on the progress of meteorology in the United States of America, and the facilities afforded in that country for the study and elucidation of meteorological questions, inquired whether any accession of relative humidity followed or accompanied the formation of cirri in a clear sky, as he had noticed when on the Peak of Tenerife that the appearance of a small cloud in what had previously been for many days a clear blue sky was followed on the next day by an increase in the relative humidity of the atmosphere.

Dr. TRIPE remarked that the statement in the last paragraph of the paper that the curved cirrus with a falling barometer presaged a storm of increasing energy, hardly accorded with his own observations, for he had several

times noticed that straight, not curved, bands of cirrus, with very thin cloud between each band, and through which the blue sky could be seen, usually foretold the approach of a severe storm.

Mr. WHIPPLE said that the question of cirrus formation had interested him very much for the past three or four years, and he was very pleased to hear Mr. Clayton's paper. The Meteorological Council, about four years ago, had asked the Kew Committee to devote attention to the photography of cirrus clouds, with a view to obtaining some knowledge of their height, rate of travel, &c. Much work was entailed by this inquiry and a considerable number of photographs were taken, but he was afraid hardly any results had been obtained. It frequently happened that, although all haste was made when conditions were favourable to obtain these pictures, all traces of the cirri had disappeared by the time the persons engaged in the work were ready at their posts; and even when pictures of the cloud were obtained, the changes in its form were so rapid that it was very difficult to identify the selected points of cloud in the various photographs taken. He had now set one of his assistants at Kew, who was a fair draughtsman, to sketch the cirri. He was very glad to find that Mr. Clayton had been so successful in describing and drawing the various formation of cirrus.

Mr. ROTCH (replying for Mr. Clayton) said that no relation between cirrus formation and the relative humidity of the atmosphere had been noted, but this could easily be investigated by means of the records of humidity registered at hourly intervals at the Blue Hill Observatory. However, it did not appear probable that the conditions near the ground would be affected by cloud formation at the height at which cirrus was believed to be, and that such variations in the humidity of the upper air might be better detected by means of the rain-band spectroscopie.

A COMPARISON BETWEEN THE JORDAN AND THE CAMPBELL-STOKES SUNSHINE RECORDERS.

By F. C. BAYARD, LL.M., F.R.Met.Soc.

[Received July 10th.—Read November 20th, 1889.]

SOMETIME ago, in the discussion following Mr. Jordan's paper on his new pattern Sunshine Recorder (*Quarterly Journal*, Vol. XIV. p. 212), I was enabled by the courtesy of Messrs. Negretti and Zambra to produce a certificate of comparison of one of Mr. Jordan's instruments with the Campbell-Stokes Recorder at the Kew Observatory. This certificate seemed to show that the monthly records, though not the daily ones, of the two instruments were practically identical. As I had had the Jordan instrument since April 1885, I had myself come to the conclusion that the Jordan registered more than the burning recorder.

The discussion on Mr. Jordan's paper gave me the impression that a comparison of the two instruments extending over some months and with a similar exposure might prove of some value. I therefore had a strong scaffolding pole, 15 feet high, erected in my garden at Wallington. On the top of this pole was a shelf properly levelled, on which was placed a 'universal burning' Recorder kindly lent by Messrs. Negretti and Zambra for the pur-

pose of the investigation. Nine inches below this top shelf I had another shelf constructed facing south and duly levelled, on which I placed the old pattern Jordan sunshine recorder. The two recorders were placed true north and south. The observations commenced on June 1st, 1888, and terminated on May 31st, 1889, and there are a complete year's records with the exception of the last 4 days in August 1888, the first 5 days in September 1888 (during which time I was away for a holiday), and September 27th, 1888, when I unfortunately put a wrong card into the burning recorder and so failed to get a trace, though I had 9.6 hours in the Jordan recorder.

Having commenced the observations, my next proceeding was to decide whether I would read the Jordan records before fixing them in water or after fixing. I decided to read them as I had hitherto done, before fixing, for I had found by long experience that the lighter traces disappeared in the process of fixing. This method of reading has one disadvantage, and a most important one, namely, that it is impossible for anyone to verify the reading made by the observer. This disadvantage I have endeavoured to minimise as much as possible by reading the papers myself. On the papers and the cards every trace has been read.

During the observations, and indeed some time previously, I found that there were defects so to speak in both instruments; these I will now mention, in order to show that I have not forgotten them. With respect to the burning recorder, it does not act at all when there is dew or water on the ball, for the ball must be quite dry before the rays penetrate it, and this defect is more especially noticeable in the morning and evening, and also after heavy showers; as far as my observations go it matters very little whether the cardboard slip is wet or dry, for when the rays once get through the ball they char the paper.

With respect to the Jordan there are two defects, or rather one defect, which is attributable to the rain; if the rain drives at all it goes in at the hole facing the direction of the rain, and runs down the paper, spoiling it wherever it touches and forms a pool in the bottom of the drum, out of which I have several times taken as much as a teaspoonful of water; also a drop of rain sometimes falls on a hole, and without penetrating the drum it causes "a blur" on the paper which it is impossible to read. It is a curious circumstance that most of the cases in which the burning records were more than the Jordan are due to rain. It is possible that these defects in each instrument may be in a great measure neutralised by covering the instrument with a bell-glass or an ordinary glass shade, a method which I have not tried owing to the very exposed position of the instruments.

I will now endeavour to deal with the observations on the subject. The Jordan instrument recorded as much or more than the burning one on every day except on June 20th and 28th, July 1st, 26th and 30th, August 2nd, 5th and 18th, September 10th and 30th, October 5th, 7th and 18th, November 4th, February 2nd, 4th, 20th and 28rd, March 25th, and May 2nd, in all 20 days out of the 355 days on which the observations were taken. The excess of the burning recorder on no occasion exceeded one hour,

which amount was only reached on two occasions, viz. September 30th and October 5th. These differences are caused partly by rain and damp, and partly by a bad light which affects the actinic more than the burning rays. On the other hand, the excess of the Jordan over the burning instrument is very great, being as much as 5.2 hours on June 8rd, 1888, and 4.5 hours on May 1st and 3rd, 1889. The monthly excess of the Jordan over the burning recorder has in the following table been expressed in the form of a percentage, in which the burning one has been considered as the standard.

INCREASE PER CENT. OF SUNLIGHT OVER BRIGHT SUNSHINE.

1888.	Sunlight.	Bright Sunshine.	Percentage of Increase.
June (30 days)	125.6	100.0	25.6
July (31 days)	125.1	100.0	25.1
August (27 days)	112.4	100.0	12.4
September (24 days)	108.4	100.0	8.4
October (31 days)	115.7	100.0	15.7
November (30 days)	136.8	100.0	36.8
December (31 days)	147.9	100.0	47.9
1889.			
January (31 days)	161.4	100.0	61.4
February (28 days)	129.1	100.0	29.1
March (31 days)	127.9	100.0	27.9
April (30 days)	140.6	100.0	40.6
May (31 days)	125.5	100.0	25.5

Mean
Percentage
of Increase
29.7

If one looks carefully at the above table it seems to present a most remarkable result, and it gives one the impression that the subject is well worthy of further systematic observations extending over a considerable period of time. There seem as it were to be two maxima, one in January, 61.4, and the other in April, 40.6; and two minima, one in September, 8.4 (this is rather doubtful, as 6 days are wanting), and the other in March, 27.9.

In indicating these results I wish to call attention to the necessity of further investigation into the properties of these two sunshine recorders; and this brings me back to the certificate mentioned in the beginning of this paper. I believe that the readings given in this certificate are correct, but that the Jordan papers were read after the fixing of the trace by water, and not before. A look at the papers and cards which I have placed in the library of the Society shows this fairly conclusively. It therefore comes to this, that the Society, before publishing the records of the Jordan, should also decide not only to publish the records in italics, as is done, but also should say whether the papers are read before or after fixing, for the monthly though not the daily values of the Jordan will be fairly comparable with the burning recorder if the papers are read after fixing, but not so if they are read before.

DISCUSSION.

Mr. JORDAN said that, in designing the photographic sunshine recorder, his endeavour was to produce an instrument capable of registering the exact time during which the sun's direct rays are strong enough to cast well-defined shadows of opaque objects, and he thought that the best form of the instrument accomplishes this result, and that the whole of such sunshine is recorded and no more; in fact, it cannot, from the nature of its construction, register *too much* sunshine. Mr. Bayard, in his paper, pointed out very clearly and correctly the relative defects of the two instruments he used; but he (Mr. Jordan) regretted very much that the old original form of photographic recorder was selected for comparison with the burning instrument. He referred to this more particularly with reference to the suggested further investigation of the subject, and because a few words of explanation would make it clear that the defects pointed out in his early recorder have been entirely obviated and guarded against in the recently altered form of the instrument. Mr. Bayard observed, with respect to the "Jordan" recorder, that two defects are noticeable in times of rain, which in stormy weather, he says, is driven into the apertures, and running down the paper, spoils its sensitiveness, and that he has often found a pool of water at the bottom of the drum. Again a drop of rain sometimes falls on an aperture, and if sunshine immediately follows, the record is so blurred that it cannot be read. He (Mr. Jordan) was quite ready to admit that the single cylinder form of the instrument used by Mr. Bayard had in a measure these defects; but in the double-chambered recorder (described in the *Quarterly Journal*, Vol. XIV. p. 212) the conditions are so altered as entirely to avoid them. In the first place, the apertures are situated in the flat side of the chamber, with which the chart does not come into contact, so that water, if it enters, cannot run down over it. And again, the apertures themselves are cut in separate discs of metal, which project above the surface, to which they are fixed (instead of being cut in the bottom of hollows filed on the outer surface of the cylinder, as in the original instrument). By these simple means any water falling on the instrument drains off on either side instead of being conducted into the apertures. It is, of course, just possible that in very heavy rain and wind a few drops falling directly on the apertures may enter the instrument, but it is only in fine splashes, which rarely, if ever, interfere with the record or spoil the sensitiveness of the paper. It would not be desirable to screen the instrument with a glass shade, as suggested, because that would introduce into the photographic system the most serious defect of the burning system by presenting a surface capable of accumulating dew and hoar frost, which in winter so seriously interfere with the working of the Campbell instrument. With respect to the washing out of the trace in the process of fixing, he found that, in the sensitised charts now supplied by Messrs. Negretti and Zambra, there is scarcely any appreciable difference before and after fixing. Of course the papers must not be left too long in water; they need only be just washed for a few seconds, in order to dissolve away the sensitive portions of the preparation which have not been acted on by the sun's rays. It is better if the charts are not used too fresh; after being sensitised, they should be kept for a few days before being used. With regard to the character of the respective traces produced by the two instruments in registering alternate periods of sunshine and cloud, he said that, on close examination of the photographic trace, it will be noticed that the record appears in well-defined indications in comparison with the burnt trace, where (under similar conditions) the effect of burning scorches the card for a considerable distance around the centre of the burn, frequently overlapping the intervals produced by passing clouds, and giving the effect of a continuous trace. In such cases it is quite possible to count up more sunshine for the Campbell instrument than would be recorded by the photographic method; and this may, perhaps, in some measure have accounted for the excess of sunshine registered by the Campbell instrument over that of the Jordan in the comparison made at the Kew Observatory referred to in Mr. Bayard's paper.

Mr. WHIPPLE, in reply to Mr. Bayard's inquiry, stated that at Kew the Jordan Sunshine Recorder sheets were fixed, washed, and dried before being tabulated.

Mr. CURTIS inquired what was the character of those portions of the traces which were lost in "fixing" the record of the Jordan recorder, and suggested that they must have been extremely faint to be so readily removed. He questioned very much whether it was allowable to regard such faint traces as being really due to actual bright sunshine, and if they had been disregarded he thought the records of the two instruments would probably not have differed very much. The statement, that the lens of the Stokes instrument being simply wet prevented its action, did not agree with his experience; hoar-frost would, of course, do so, but not a film of water.

Mr. BAYARD said that he had used the old pattern of the Jordan Recorder because the new form of instrument was not available when the comparison was commenced. The lighter traces of the Jordan records which became invisible after fixing the paper in water, appeared to be of the same character as the strong traces, and their outline was just as sharply defined, the only difference being in the shade of the trace.

CLIMATOLOGICAL OBSERVATIONS AT BALLYBOLEY, CO. ANTRIM.

By S. A. HILL, B.Sc., F.R.Met.Soc.

(Abstract.)

[Received September 6th.—Read November 20th, 1889.]

THE observations summarised below were made once a day at 8.30 a.m. by Mr. Thomas H. Craig, with duly-verified instruments, the air temperatures being taken in a Stevenson's screen 4 ft. above the ground, and the rain gauge being 1 ft. 4 in. above the soil. The exact spot where they are made is lat. 54°48' N and long. 5°59' W, in the Townland of Ballyboley, close to the Ballyclare Junction of the Larne and Ballymena Railway, near the foot of the steep slope between Cairn-an-Ard and the watershed between the Larne and the Six-Mile Water. The height above sea level is between 400 ft. and 450 ft. The observations are complete for the 5 years 1884-88, with the exception of the maximum temperature in the shade for January 1884, the value for which has been estimated by differentiation from readings at adjacent stations.

The highest air temperature recorded during the period under observation was 80°, and the lowest 14°. The range of the monthly means was only 19°·7. The months of June, July and August were free from frosts during the whole period, and only one frosty night was observed in September. Frosts are more frequent in the bottom of the valley, for, owing to the slope of the ground, the air cooled by nocturnal radiation flows down and collects there.

With respect to the rainfall, notwithstanding the low mean temperature, snow does not usually fall on more than 10 days during the year. Large falls are scarce, and, during the period, the three largest occurred in the year

1888, viz. 1·60 in. on May 29th, 1·80 in. on July 28th, and 1·68 in. on December 18th.

Table I. comprises a summary of the Temperature observations, and Table II. a summary of the Rainfall observations.

TABLE I.

AIR TEMPERATURES, 1884-1888.

Months.	Means.			Extremes.				Means at 8.30 a.m.		
	Max.	Min.	Mean.	Max.	Year.	Min.	Year.	Dry.	Wet.	Relative Humidity.
January ..	42·0	33·6	37·8	54·0	1888	14·0	1887	37·9	37·4	96
February ..	42·7	33·2	38·0	55·0	1885	22·0	1885	37·7	36·7	91
March	44·5	32·9	38·7	60·0	1887	18·0	1888	37·9	37·0	92
April	51·0	36·2	43·6	68·0	1886	27·0	1887	43·2	41·3	85
May	56·7	40·6	48·7	69·0	1884	29·0	1887	49·5	46·5	79
June	62·5	46·5	54·5	80·0	1887	37·0	1885	54·8	52·5	85
July	65·1	49·6	57·4	80·0	1885	37·0	1887	56·1	54·2	87
August ..	63·5	49·1	56·3	76·0	1884	37·0	1885	56·7	54·6	87
September	59·5	46·0	52·7	71·0	1884	35·0	1887	52·5	51·3	91
October	52·0	40·5	46·3	65·0	1886	30·0	1887	45·9	44·5	89
November ..	46·3	37·1	41·7	57·0	1885	24·0	1887	42·0	41·2	93
December ..	42·2	33·1	37·7	55·0	1888	14·0	1886	37·2	36·7	95
Mean ..	52·3	39·9	46·1	..	..	..	..	46·0	44·5	89

TABLE II.

RAINFALL, 1884-1888.

Months.	Totals.					Means.	
	1884.	1885.	1886.	1887.	1888.	1884 to 1888.	No. of Days on which it fell.
	In.	In.	In.	In.	In.	In.	
January	6·55	2·53	5·31	2·78	2·30	3·89	17
February	3·17	4·39	2·42	1·60	0·84	2·49	15
March	4·68	2·25	2·24	1·49	3·96	2·92	16
April	2·26	3·63	2·42	1·65	1·15	2·22	12
May	2·27	2·19	3·00	2·11	3·99	2·71	15
June	1·37	0·74	1·52	0·49	3·64	1·56	9
July	3·11	2·20	3·01	2·71	6·92	3·59	16
August	2·57	2·75	2·56	2·35	3·84	2·81	15
September	3·51	5·22	3·51	4·13	1·73	3·62	15
October	2·66	4·15	5·00	1·98	1·87	3·13	15
November	3·41	2·36	4·13	2·85	2·16	3·78	16
December	4·18	2·00	5·46	2·97	2·27	3·58	16
Totals	39·74	34·41	40·58	27·11	39·67	36·30	177

Report of the Wind Force Committee on the Factor of the Kew Pattern Robinson Anemometer.

DRAWN UP BY W. H. DINES, B.A., F.R.Met.Soc.

[Read December 18th, 1889.]

In the Report of the Wind Force Committee¹ read before the Society in May 1888 the results of some experiments with various anemometers were given, but it was stated that no correction for the natural wind had been applied. Since then a considerable number of further experiments have been made, the total now reaching 103. As previously stated, each experiment consisted of a 15 minutes run of the anemometer in a circle of 58 feet diameter.

Out of these experiments 12 have been made with the friction of the anemometer artificially increased, 7 with a variable velocity, and 14 with the plane of the cups inclined at an angle to the direction of motion. The remaining experiments have been arranged in 5 groups, each group consisting of those experiments in which the velocity was nearest to 5, 15, 25, 35, and 45 miles per hour respectively. Each group has again been split up into two parts, one part consisting of those experiments during which the

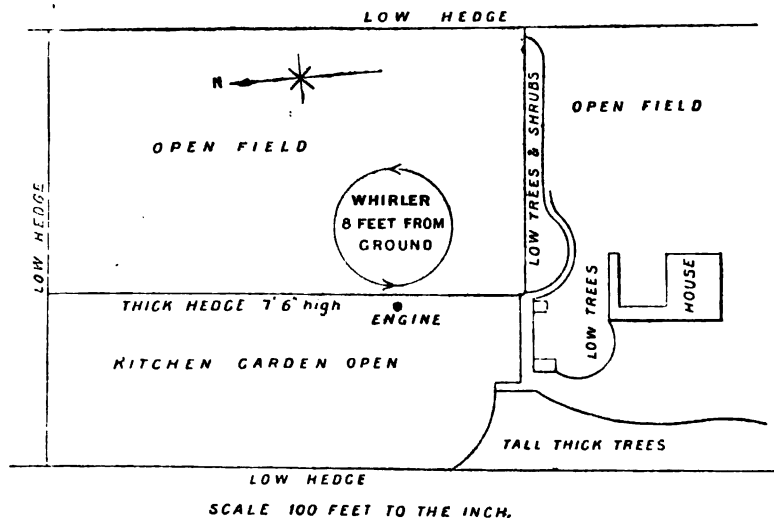


FIG. 1.—Showing the position of the Whirler and its surroundings.

amount of natural wind registered was less than $\frac{1}{4}$ mile, and the other part, of those during which the amount registered exceeded the $\frac{1}{4}$ mile. On many of the days there was not sufficient wind to move any of the anemometers at

all, and although such days may not have been absolutely calm, it may be taken for granted that the wind velocity was less than 8 miles per hour. With a few exceptions the experiments have been made on calm days, the highest wind velocity ever registered during an experiment being about 8 miles per hour. On account of the uncertainty attending the correction for the natural wind it has been thought better to collect the experiments into groups rather than to treat them separately. It is pretty certain that in the groups headed "Calm," the average velocity has not exceeded 8 miles per hour, for during most of these experiments no wind at all was registered. In the groups headed "Rough," perhaps 6 miles per hour may be taken as the highest possible value for the average. The anemometer employed to measure it, when tested on the whirling machine, was accurate at all velocities exceeding 5 miles per hour, and would begin to turn at a velocity of about 3 miles per hour. Its readings give an average of a little over 4 miles an hour, but since on almost all the days on which experiments were made there were times when no anemometer would move at all, it may be well to take a higher value for the average.

TABLE I.

Velocity in miles per hour.	Calm.		Rough.	
	Factor.	No. of experiments.	Factor.	No. of experiments.
Between 40 and 50 ...	2.22	6	2.12	8
„ 30 „ 40 ...	2.19	5	2.10	7
„ 20 „ 30 ...	2.15	10	2.10	14
„ 10 „ 20 ...	2.45	5	2.09	5

DETAILS OF EXPERIMENTS.

Rate in miles per hour.	Factor.	Wind in miles measured during the fifteen minutes.	Direction of wind.
11	1.90	1.8	N
11	2.19	.5	NE
11	2.20	1.1	N
12	2.49	0	E
12	2.44	0	E
18	2.50	0	E
18	2.28	0	W
15	2.12	.7	N
16	2.87	.4	S
20	2.08	1.2	N
20	1.83	2.1	NE
20	2.11	.6	N
21	2.04	1.9	NE
21	2.14	0	W
21	2.29	0	S
22	2.18	.7	NE

TABLE I.—*Continued.*

DETAILS OF EXPERIMENTS.

Rate in miles per hour.	Factor.	Wind in miles measured during the fifteen minutes.	Direction of wind.
23	2.05	1.0	NW
24	2.16	.4	NE
24	2.05	0	S
25	2.26	1.0	E
25	2.09	.9	N
25	2.10	.7	NW
25	2.15	0	W
26	2.09	.8	NW
27	2.18	0	W
28	2.04	2.0	NE
28	2.08	.9	E
28	2.18	0	SW
29	2.10	1.0	NW
29	2.16	0	W
29	2.28	.7	NE
30	2.12	1.1	N
30	2.18	0	S
30	2.18	.8	NE
30	2.29	.4	NE
31	2.08	.8	N
32	2.22	0	W
34	2.08	.7	NW
34	2.07	.9	NW
35	2.10	.7	N
35	2.16	0	S
35	2.18	1.5 (?)	NE
37	2.18	.7	N
37	2.08	.8	NW
37	2.15	.4	NE
37	2.29	0	N
38	2.14	.2	N
40	2.28	0	S
40	2.10	.7	N
40	2.10	.5	NW
41	2.11	.7	N
41	2.15	0	SW
44	2.10	1.2	W
44	2.21	1.5	N
45	2.12	.8	W
48	2.26	1	NE

TABLE I.—*Continued.*

DETAILS OF EXPERIMENTS.

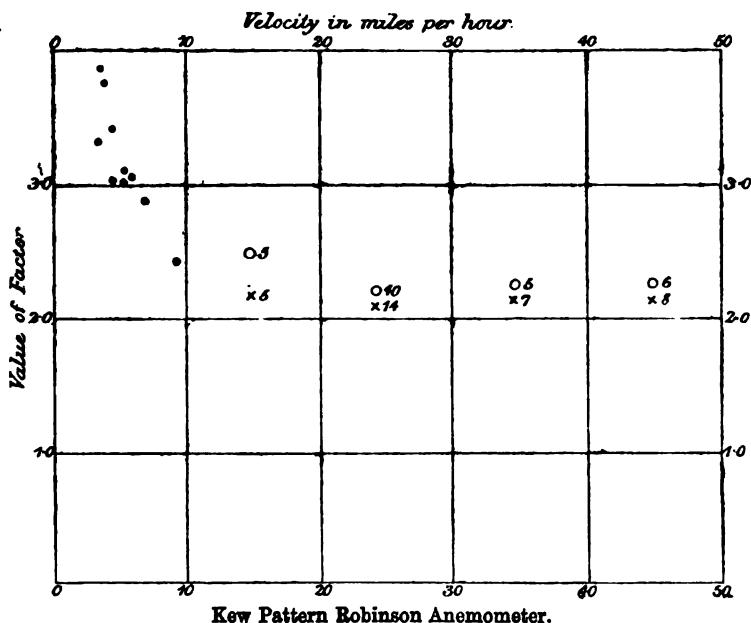
Rate in miles per hour.	Factor.	Wind in miles measured during the fifteen minutes.	Direction of wind.
48	2.29	0	W
48	2.26	0	N
48	2.02	1.5 (?)	NE
49	2.15	0	W
50	2.19	1.1	W

Low speed experiments, all made on calm days :—

Miles per hour.	Factor.	Miles per hour.	Factor.
8	8.92	5	8.00
8	8.88	5	8.09
8½	*8.77	6	*8.02
4	*8.40	7	2.89
4	8.01	9	2.48

No wind was registered during any of these low speed experiments, but the three marked thus * were made on a most exceptionally calm day.

FIG. 2.



The low speed experiments are shown separately thus •

The groups of experiments made on calm days thus ○

Ditto on rough days thus ×

The figures relate to the number of experiments on which each result is based.

In discussing these figures, there are three points which must be taken into consideration; they are, the possibility of the existence of induced eddies ('*Mitwind*'), the effect of the increased friction due to the centrifugal force and gyroscopic action, and the action of the natural wind. The readings of two other anemometers placed on the long arm near the Kew standard throw some light upon these points. The first was a small Robinson anemometer having 1 in. cups on 1.75 in. arms, placed 2 feet nearer the axis of the whirler than the standard. For fear of damage it was not tested at the highest speeds, but unlike the standard it shows a very slight decrease in the value of the factor as the speed increases. It may be of interest to state that the factor of this instrument, deduced from 20 experiments at rates between 10 and 80 miles per hour, is 2.74, and that the experiments made with it are far more consistent among themselves than those made with the Kew standard. It would be affected like the other, but being so much lighter it would take up the proper velocity of rotation more quickly. At one foot from the standard a Helicoid anemometer was placed. The records of this instrument are certainly independent of any friction due to the centrifugal force, since a far greater amount of friction caused artificially had no effect upon it. It has also been tried on the whirling machine, by itself, at speeds up to 70 miles an hour without showing any variation. It will be seen from the tables that the factor of the Kew standard shows a tendency to increase with the velocity on the calm days, rising from its lowest value 2.15, at 25 miles an hour, to 2.22 at 45 miles an hour. Since this increase is hardly noticeable upon the rough days, it is natural to suppose that it may be due to induced eddies, but there is no other evidence in favour of this supposition. The results of the experiments with the small Robinson and the Helicoid anemometer show no sign of it, for it is obvious that it is only on quite calm days that any induced eddies could exist, and these instruments do not show a difference of more than $\frac{1}{4}$ per cent. between the rough and calm days. Also damp vegetation has often been burnt under the whirler to see if any eddy could be detected, but always with a negative result.

The next point to be considered is the effect of the centrifugal force and the gyroscopic action. The experiments, details of which are given in Table II., were made to elucidate this. In the ordinary way the cups would begin to turn with a weight of 40 grains placed in one of them. In these experiments the friction was increased by a brake, and the weight given in the table is the mean of the two weights required just to move the cups at the beginning and end of the experiment.

TABLE II.

Weight in ounces.	Natural Wind in miles during experiment.	Rate in miles per hour.	Factor.
$\frac{1}{4}$	·5	89	2·15
$\frac{1}{4}$	·6	41	2·17
8	·6	45	2·88
8	·2	24	8·62
8	0	27	4·78
2	·1	29	2·75
8	·1	80	2·41
8	6	81	2·40
8	·1	85	2·98
$8\frac{1}{2}$	·1	80	8·20
2	·1	85	2·88
2	·1	85	2·85

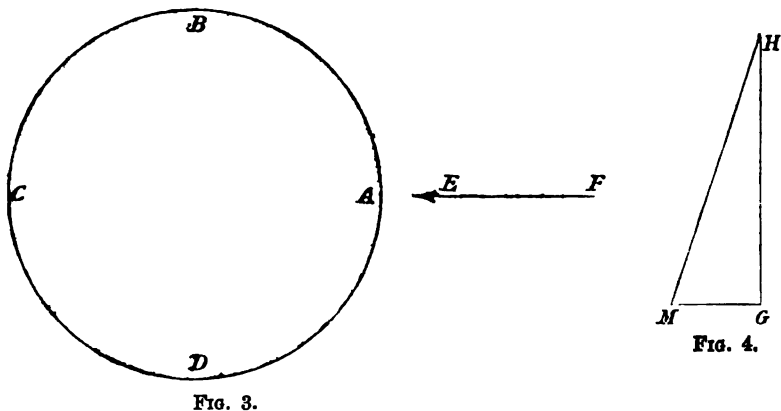
The great difference between the figures for the calm and rough days shows that the natural wind is a very important matter. The question of the correction for the wind is complicated by the radial position of the axis of the anemometer. It will be seen at once that in certain parts of the circle the wind direction will not be parallel to the plane of the cups, and the question arises how an anemometer will act under these circumstances. Eight experiments were made with the axis of the anemometer inclined at an angle of 10° to the long arm, and gave 2·81 as the mean value of the factor. Six experiments made with an angle of 37° gave the low mean value of 2·18. However, it is only the former set that are of interest in this connection, for with a wind velocity of 6 miles per hour and a rate of 25 miles per hour for the anemometer, the angle between the plane of the cups and the direction in which the air passes over the anemometer can barely exceed 10° in any part of the circle. The mean value of the factor for the normal position is 2·15, and since the ratio of 2·81 to 2·15 is greater than that of $\cos 0^\circ$ to $\cos 10^\circ$, it follows that a little wind blowing during an experiment ought to lessen rather than increase the number of turns of the cups, and thereby increase the value of the factor.

Since the whole question turns upon this point, it may be well to explain it further. In two parts of the circle the wind is blowing across the direction of the anemometer, with the result that it strikes the plane of the cups at a small angle, and also that the relative velocity is increased. The conditions are the same as if the pole on which an anemometer is mounted were inclined towards the wind and at the same time the wind velocity increased. If under these conditions the increased velocity more than compensates for the oblique position of the cups, the registration will be increased, and *vice versa*. The experiments with the inclined axis show that the influence of the oblique position is predominant when the angle is 10° , and since in

most of the experiments we can see, either by a diagram drawn to scale or by reference to a table of tangents, that the angle must be less than 10° , we are justified in the conclusion, that so far as this point is concerned the natural wind should increase the value of the factor.

Experiments have also been made to determine the extent to which the friction would be altered by the increased pressure on the bearings. At 80 miles an hour the actual pressures are 8 or 4 times as great as when the anemometer is at rest, but it was found that notwithstanding this, when the instrument was weighted in such a way that the actual stresses were made to correspond with those induced by a speed of 80 miles an hour on the whirler, only 60 grains were required instead of 40. This small alteration was quite unexpected, and is probably due to the ball bearings; it shows however that the centrifugal force and gyroscopic action have but a very trifling effect upon these experiments.¹

Diagrams explaining the action of the natural wind.



In fig. 3 $ABCD$ represents the circle in which the instrument is moving and FE the direction of the wind.

Let V be the velocity of the instrument, and v of the wind.

At B the relative velocity is $V - v$.

At D " " " " $V + v$.

At A and C it is $\sqrt{V^2 + v^2}$

So far as the parts of the circle at B and D are concerned, the opposite

¹ The forces are a direct outward force $\frac{mv^2}{r}$ parallel to the axis, caused by the centrifugal force; and a couple in a vertical plane due to the gyroscopic action equal to $mk^2w_1w_2$, when k is the radius of gyration, w_1 is the angular velocity of the anemometer and w_2 of the whirler. Since $w_1 = 6.7w_2$ very nearly, taking 2.15 for the factor, both these forces vary as v^2 , and the conditions may be reproduced by applying a force $\frac{mv^2}{r}$ parallel to the axis of the anemometer and at a distance $\frac{6.7k^2}{r}$ from it.

effects cancel each other, but the effect is the same at A and C , and hence on the whole the mean value of the relative velocity is raised.

Fig. 4 shows the action at A and C . GM represents the motion of the wind, GH that of the instrument, and MH the relative motion. If drawn to scale, the air strikes the plane of the cups at an angle equal to MHG .

When this angle is 10° the instrument loses from 6 to 7 per cent. on account of its oblique position, but HM is greater than HG by less than 2 per cent., so that there is a loss instead of a gain at the parts of the circle near A and C .

On the assumption generally made, the correction for the natural wind is a very small one, excepting at the low velocities; but the figures given in the tables render it clear that, actually, a little more or less wind blowing during an experiment has an important effect upon the result. The way in which the difference between the factors obtained on rough and calm days first decreases and then again increases with the velocity is very curious. The increase seems to be too regular to be due to accidental errors, but, on the other hand, it is very strange that a little wind should make more difference when the speed is 45 miles an hour than when it is only 25 miles. Apart from the possibility of induced eddies I can only suggest one explanation. When the speed is 45 miles an hour the circle is completed in about 8 seconds, and consequently the motion of the air past the anemometer attains its maximum and minimum values at intervals of $1\frac{1}{2}$ seconds. When the speed is 25 miles an hour these maximum and minimum values occur at intervals of nearly 8 seconds.

It may be well to describe here an experiment relating to this subject. Taking the factor as 8, about 5 turns of the cups should correspond to one of the whirling machine, but it is possible to obtain as many as 10 to 12 turns of the cups to each turn of the machine. This is managed as follows:—On a perfectly calm day one complete turn is given to the whirler and it is then allowed to stand still until the cups have nearly come to rest, repeating this process a few times the factor comes out less than 1.5. This shows how much more ready the cups are to take up their proper velocity than to lose it, and it seems probable that many of the discrepancies which have appeared in connection with experiments on this subject are due to this curious behaviour of the Robinson anemometer in a variable wind. The Kew standard pattern is especially liable to this on account of its large “moment of inertia.”

Unfortunately it is difficult to obtain a variable speed of short period on the whirling machine when the average speed is at all great. In the 7 experiments which have been made in this way the intervals between the times of maximum and minimum velocity have been from 20 to 30 seconds, and the velocities have ranged from 10 to 40 miles per hour; the mean value of the factor deduced from these is 2.17, that is, about the average, and this shows that when the period of variation is of any length, and the velocity never reaches a very low value, the instrument records a velocity departing but little from the mean value. It must be remembered, however, that at a rate

of 10 miles an hour the factor is considerably above 2·17, so that the result shows that a variable instead of a uniform speed does give a lower factor. There can be but little doubt that the small instrument with the 1 in. cups is much more correct than the Kew standard when the wind is variable, and the greater consistency of the results obtained with it in these experiments is thus explained. There is, however, a reverse side to this, the small instrument is largely dependent upon very little change in the friction, and when placed by the side of another larger instrument in the winter, it was found that its readings were greatly affected by the temperature, presumably on account of the viscosity of the oil. This was so marked, that upon a frosty day its sluggishness was apparent to the eye.

It remains to consider the most probable value of the factor; and it must be confessed at once that the experiments do not show with any certainty the ratio of the wind's velocity to that of the cups for a uniform rate. This perhaps is of little consequence, inasmuch as the instrument is never required in practice to measure a uniform velocity.

For the reasons given above there can be little risk of error in neglecting the correction for induced eddies or for the increased friction caused by the circular motion. It has also been shown that if we assume the instrument to record the mean velocity to which it is exposed, it is almost certain that in virtue of the radial position of the axis, the correction for the natural wind is negative. It is also certain on the above assumption, that for any position of the axis the correction must be very small at all the higher speeds. The formula for this correction is given by Sir G. Stokes in his paper on the Crystal Palace experiments. It is easily obtained by anyone acquainted with the notation of the integral calculus, and its truth is entirely beyond dispute. The conclusion that the instrument is greatly affected by the variability of the wind to which it is exposed seems to be irresistible, and if so, the exact value of the factor must depend upon the nature of the wind as well as upon the mean velocity. There is evidence to show that during a gale the variations of velocity are sometimes of great extent and frequency, and there can be but little doubt that in such a case the factor is less than 2·15. The one point which does seem clear is, that for anemometers of the Kew pattern the value 8 is far too high, and consequently that the registered wind velocities are considerably in excess of the true amount.

Since sending in the Report to the Wind Force Committee, the following series of experiments have been made:—

(1.) The ball bearings of the anemometer were removed and plane bearings substituted. The mean value of the factor, deduced from 7 trials at about 80 miles per hour, was then found to be 2·26; that is an increase of 5 per cent. This is satisfactory, inasmuch as it partially explains the higher value given by the Crystal Palace experiments, especially when it is remembered that the long arm in that case was shorter than the one at Hersham, and therefore the centrifugal force and friction greater.

(2.) Arrangements have been made by which the maximum pressure upon

a foot circular pressure plate could be compared with the maximum speed of rotation of the cups; but, in so far as the determination of the factor is concerned, the plan is a total failure. The maximum pressure always occurs before the cups have taken up their highest speed, and it is not unusual for it to occur in quite a different gust of wind to that in which the cups attain their greatest rate, the rate of the cups depending upon the duration as well as upon the strength of the gust.

The corresponding values are given in Table III.

(8.) Comparisons have been made between the Kew pattern anemometer and a light air meter. The constants of the air meter were carefully determined from time to time upon the whirling machine, and it was exposed by the side of the anemometer about 15 feet above the tower at Woodside, Hershham. The recording dial of the air meter, which was kept facing the wind by a vane, was allowed to remain in action while the centres of the cups travelled over 1,000 feet (corresponding to $79\frac{1}{2}$ revolutions), and thus the distance recorded by the air meter, after correction and cutting off the last three figures as decimals, gave the factor. It was hoped that, choosing so short a distance for each comparison, a fairly uniform speed would be obtained throughout, but such has not been the case. It will be seen that the values (Table IV.) are anything but consistent, but are always far less than the values for the same mean velocity deduced from direct trial on the whirling machine, a result which I believe to be due to the variability of the wind.

TABLE III.

Maximum pressure in lbs. per square foot.	Maximum rate of revolution of cups in decimals of a complete turn per second.	Factor of anemometer deduced from comparison must be less than
·72	·60	2·78
·90	·66	2·84
·98	·71	2·66
·95	·75	2·55
1·12	·91	2·28
1·75	1·08	2·41
1·75	1·20	2·17
2·20	1·28	2·16
2·45	1·44	2·18

In the above table the maximum rate of the wind was calculated from the maximum pressure, using the experimental result obtained from the same pressure plate, and thus the factor was found which would give the corresponding maximum rate of revolution of the cups.

TABLE IV.

Factor.	Approximate mean rate in miles per hour.	Factor.	Mean rate.
Nov. 25th, Mornng.		Nov. 26th	
2.15	7	1.87	4
1.89	8	2.72	4
2.18	8	2.20	5
1.77	10	2.41	5
2.14	18	2.72	5
2.18	18	2.80	8
1.77	15		
Nov. 25th, Afternoon.		Nov. 27th	
2.27	6	2.80	8
2.18	7	2.20	9
2.22	7	2.28	11
2.28	8	2.17	13
2.18	8		
2.47	8		
2.25	8		
2.27	10		
2.24	10		
2.22	10		
2.22	12		
2.22	12		

APPENDIX.

LITERATURE ON THE THEORY OF ANEMOMETERS.

ABBE, C.—Treatise on Meteorological Apparatus and Methods. *Appendix 46, Ann. Rep. Chief Sig. Off.* 1887.

APPENDIX TO THE REPORTS of the Court and Evidence taken upon the Inquiry into the Tay Bridge disaster.

BENDER, C. B.—Design of Structures to resist wind pressure. *Proc. Inst. C.E.* Vol. LXIX. Part III.

BOURDON, E.—L'Anémomètre multiplicateur de M. E. Bourdon, père. *Annuaire de la Soc. Met. de France.* Tome XXX. p. 120, 1882.

CASELLA, L. M.—Description of an Altazimuth Anemometer, for continuously recording the vertical angle, as well as the horizontal direction and force of the wind. *Quart. Journ. Roy. Met. Soc.* Vol. XII. p. 246, 1886.

CATOR, C. O. F.—Description of a New Anemometer for self-registering the pressure, velocity and direction of the wind. *Proc. Met. Soc.* Vol. III. p. 49.

CATOR, C. O. F.—On certain defects in Anemometric Registration. *Quart. Journ. Met. Soc.* Vol. I. p. 103.

CATOR, C. O. F.—Some remarks on the Estimation of Wind Force, and on the Relation between Pressure and Velocity. *Quart. Journ. Met. Soc.* Vol. II. p. 171.

COUSTÉ, M.—Projet d'un Baranémographe. *Annuaire de la Soc. Met. de France.* Tome XXX. p. 179, 1882.

CURTIS, R. H.—Comparison of Robinson's and Osler's Anemometers, with remarks on anemometry in general. *Quart. Jour. Roy. Met. Soc.* Vol. VII. p. 205.

CURTIS, R. H., and BURTON, C. E.—Notes of Experiments on the Distribution of Pressure upon Flat Surfaces. *Quart. Jour. Roy. Met. Soc.* Vol. VIII. p. 139. Also Second Series. Vol. IX. p. 221.

- DECHEVRENS, Rev. P.—Sur l'Inclinaison des vents.
- DOHRANDT, Dr. F.—Bestimmung der Anemometer-Constanten. *Repertorium für Meteorologie*, Band IV. No. 5, 1874, and VI. No. 5, 1878.
- FINES, Dr.—Vent, sa direction et sa force observées à Perpignan avec des anémomètres électriques. 1873.
- GAUDARD, J.—The resistance of viaducts to sudden gusts of wind. *Proc. Inst. C.E.* Vol. LXIX. Part III.
- GARRIGOU-LAGRANGE, P.—Sur un enregistreur des courants ascendants et descendants de l'atmosphère. *Annuaire de la Soc. Met. de France*. Tome XXXV. p. 124, 1887.
- HATON DE LA GOUPILLIÈRE.—Rapport sur les anémomètres enregistreurs de M. Bourdon.
- KÖPPEN, Dr. W.—Notiz über die Rückführung der Anemometerangaben der Stationen der Seewarte auf absolute Maass und über das Verhältniss von Beaufort's Scala zur Windgeschwindigkeit. *Zeitschrift der Oester. Gesell. für Met.* Band XIV. p. 302.
- MARVIN, Prof. C. V.—Measurements of Wind Velocity. Results of Recent Experiments. *American Met. Journ.* Vol. V. p. 552, 1889.
- PEGGS, J. W.—On the structural Damage caused by the gale of Oct. 13-14, 1881. *Quart. Journ. Met. Soc.* Vol. VIII. p. 29.
- ROBINSON, Rev. T. R., D.D., F.R.S.—On the determination of the constants of the cup anemometer by experiments with the whirling machine. *Phil. Trans. Roy. Soc.* 1878-1880.
- RUNDLUND, C. A.—Om Robinson's Anemometer. *Academical Thesis, Upsala*, 1877.
- STANLEY, W. F.—An integrating anemometer. *Quart. Journ. Roy. Met. Soc.* Vol. IX. p. 208, 1883.
- STELLING, E.—Verifikation Robinsonscher Anemometer bei grossen Geschwindigkeiten. *Repertorium für Meteorologie*. Band IX. 1885.
- STOKES, Prof. G. G., F.R.S.—Discussion of the results of some experiments with whirled anemometers. *Proc. Roy. Soc.* Vol. XXXII. p. 170, 1881.
- STOW, Rev. F. W.—On large and small anemometers. *Quart. Jour. Roy. Met. Soc.* Vol. I. p. 41.
- THIESEN, M.—Zur Theorie der Windstärke-Tafel. *Repertorium für Meteorologie*. Tome IV. No. 9, 1875.
- WILD, Dr. H.—Die Constanten der Anemometer. *Zeitschrift der oester. Gesell. für Met.* Band VIII. p. 282, 1873.
- WILD, Dr. H.—Ueber den gegenwärtigen Zustand der Anemometrie und über Anemometer-verification. *Bulletin de l'Acad. St. Petersburg*. Vol. XXIII. p. 176, 1876.
- WIND PRESSURE ON RAILWAY STRUCTURES.—Report of the Committee.

DISCUSSION.

The PRESIDENT (Dr. Marcet) said that Mr. Dines's papers gave evidence of great care and research, and the results were very important: although the exact value of the factor for the Robinson anemometer had not yet been determined, still, an approximation had been obtained which could not fail to be of much value.

Mr. WHIPPLE said that he felt that the investigation could not be in better hands than Mr. Dines's, and he believed that in the matter of the Robinson anemometer all that it was practically possible to do with this instrument had been done.

Mr. BAYARD said that it appeared from the Report of the Committee that all the work done by the Kew pattern Robinson Anemometer was, if not quite worthless, at any rate of a value which was certainly problematic. The smaller anemometers, according to previous experiments, seemed to give much better results, and he would like to know whether the indications of these smaller instruments were of greater value, and whether the observations obtained from them could be utilised.

Mr. SYMONS said that it was unfortunate that anemometry was in such a serious condition as the paper seemed to indicate. His experience with anemometers was very small, but there appeared to him to be no necessity for using

the ponderous cups of the Kew pattern. He had quite recently received an instrument from Richard, of Paris, part of which was an anemometer, consisting of a fan about 18 inches in diameter, very much like an ordinary air meter, but, of course, larger, and more resembling the fan of Whewell's anemometer, and having the blades of the fan made of aluminium, and slightly curved, and the merest touch was sufficient to set the fan spinning.

Captain WILSON-BARKER inquired whether any experiments had been made with other forms of anemometers, as it seemed of little use experimenting further with the Robinson form. He thought the Hagemann form of gauge would give good results.

Mr. MUNRO said that he did not think it was possible to improve the form of the Robinson anemometer; and in the case of the Kew pattern it was not easy to see how the effect of momentum could be overcome. He was satisfied that Mr. Dines's Helicoid anemometer was a better instrument than any other anemometer in existence. He thought that now it was so clearly established that the factor 3 for the Robinson anemometer was wrong, some factor nearer the truth should be used. He believed, from what he had heard, that the fan pattern of anemometer, like that of Richard described by Mr. Symons, was not reliable.

MR. CURTIS said, with reference to the suggested use of small anemometers, that it should be remembered that when anemometers were put up in exposed places, such as Holyhead and other localities on our western coasts, they have to face much greater wind forces than are experienced at an inland station or in a city like London, and therefore they require to be very substantially made. Even with the precautions which are now taken it sometimes happens that an arm is torn away from the rest of the instrument. As to the use of electricity, if an effective system of electrical contacts could be arranged it would doubtless be a great advantage, because by its use difficulties due to the necessity which now exists for placing the instrument on buildings—always more or less unsuitable—could then be avoided, and something like uniformity could be secured in the conditions of exposure. But the great obstacle to its use lay in the difficulty involved in keeping the contacts, necessarily exposed to the weather, in good working order; and some recent experience of this at Valencia had shown that the difficulty was exceedingly great. At the same time, a comparison which had been made there between two similar instruments working side by side, but the one recording in the ordinary way and the other by means of an electrical arrangement, had shown a very close agreement between the records of the two. With reference to the effect of variation in the wind-force upon the speed of the cups, he had found, from some experiments he had himself carried out, that the Robinson cups took up any increase in the speed of the air passing over them very readily, and he had supposed that, when the wind fell again, they parted with their motion as speedily; but Mr. Dines's experiments seemed to show that such was not the case. The variations in the force of the wind in short intervals of time (as shown in enlargements of records from Osler's anemometer exhibited to the Meeting) were sometimes extremely great. The indications of the "bridled" anemometer at Holyhead also showed this feature remarkably well. During a gale in October 1889 the record from this instrument showed several remarkable oscillations of this character, and in one instance the pencil was driven considerably beyond the scale on the occasion of a strong gust of wind. These gusts appeared to be regular in their recurrence, and to come in groups, with a tolerably uniform interval of time between them; indeed, there appeared to be two distinct sets of gusts, the one occurring when the general strength of the wind was comparatively low, and the other when its average strength was much greater, as if there was a regular pulsation or set of waves in the air, with a distinct set of sudden oscillation occurring both with the trough and the crest of the waves. As the gale died out, these pulsations became less distinct, and gradually died out.

Mr. SCOTT asked if the fan instruments used in the Metropolitan Railway Tunnels, referred to by Mr. Munro, had been really Whewell's Anemometers, or Airmeters like those sold at present. Dr. Whewell described his anemometer as a kind of small windmill with 8 sails inclined at an angle of 45° to the wind and kept facing the wind by a vane. The registering apparatus was an essential part of this instrument.

Mr. MUNRO remarked that the Kew-pattern anemometer used by Mr. Dines

in these experiments was slightly heavier (perhaps one pound) than the instrument at Kew. The great difficulty in constructing the cup anemometer has been to make it of sufficient strength to stand the hard wear and tear which it is subject to.

Mr. LAUGHTON thought that Mr. Dines's observations dealt a death-blow to the Robinson's anemometer. He had long felt a distrust of the instrument, and had said, many years ago, that the first and most pressing need of anemometry was a new type of head. It was satisfactory to find this opinion so fully confirmed by the results of Mr. Dines's experiments. He entirely agreed with Mr. Whipple, that little good was to be expected from further experiments with Robinson's cups; but he earnestly hoped that now, or at some later period, Mr. Dines would be able to carry on some investigations with other forms of anemometers, and more especially with his own Helicoid and the Hagemann pipe, both of which seem full of promise, when once we are lifted clear of the rut which has so long confined our footsteps.

Prof. A. S. HERSCHEL said that Mr. Dines having recently shown him in actual progress his process of proving anemometers, and of measuring wind-pressure coefficients on his large steam whirling-crane at Hershham, enabling him to note the perfect working action of its self-adjusting and recording mechanisms, and making him familiar with his many happy inventions of practical improvements in wind and weather recording instruments, he wished to say a few words on what he regarded as some points of great value in the papers. He would desire in the first place to notice especially the conspicuous ingenuity with which the experiments described had been conducted, and the mathematical resource and skill with which, in deducing the results, the probable sources of error were discussed and sought to be allowed for, or eliminated, as being such, he thought, as must command great confidence in the inferences and conclusions drawn by the Wind Force Committee from the long and carefully pursued series of experiments which had been recorded. From these it appeared to be now quite certain, that the Robinson form of anemometer is not such a direct and simple indicator of the wind's velocity as it has hitherto been generally supposed to be. On the other hand, the ratio of the wind's speed to that of the cups, if not actually constant, yet only shows small changes, as if some modification could perhaps be found which would render it more stable; and it is very decidedly shown to be more nearly 2 : 1 than 3 : 1, which was the value used, and thenceforth adopted, in the theory of the instrument first proposed by its inventor. As a prominent example of the great inventive skill employed in these experiments, their complete establishment of the exactitude of Hutton's law of wind pressure, that for a given obstructing surface (without any limitations apparently of the outline, or solid figure), the pressure of a blast varies as the square of the wind's velocity, shown to be strictly true for a pretty considerable range of velocities, by balancing the centrifugal action of a small lever's weight against that fluid pressure at the circulating arm-end of the whirling-crane, was a result of the inquiry upon which, by itself alone, the Society might be felicitated which had subsidised these experiments, and which had now quite recently published in its *Quarterly Journal* this very significant outcome, with many most important variations on it, of the investigation. If then this law may be trusted strictly in the case at least of a flat pressure-board, we may perhaps hopefully expect that the form of anemometer introduced by Mr. Follett Osler, recording wind-currents by their pressures, of some of whose registrations Mr. Dines had shown them an interesting diagram to illustrate his paper, will in the end prove practically to be the most trustworthy form of wind-recording instrument; and he would like to ask Mr. Dines if they might not now consider that the pressure of a wind upon the flat square pressure-plate of Osler's anemometer may be regarded as always exactly proportional to the square of the wind's velocity?

In connection with the reading of the second paper, an instrument was referred to which was shown upon the table, for indicating directly the velocity of a fluid current by first making the current produce its natural fluid pressure. The new instrument had not, he thought, been dilated on at sufficient length by Mr. Dines for its very perfect action to be made known to the meeting as fully and distinctly as the ingenuity of its construction merited. Prof. Herschel however hoped that he would not be disclosing more of this instrument's most elegant contrivance than Mr. Dines himself was anxious to divulge at present, if he tried to explain to the

Society a little more fully than Mr. Dines had been content to do, the beautiful simplicity and the remarkable ingenuity of its construction.

The head of pressure due to air velocity can either be shown directly by a Lind's wind-gauge in inches of water-column supported in the straight limbs of the bent water-tube, when the wind-current blows directly into the open mouth of the gauge-tube, or else, if the current gives rotation to a Robinson's, or Lownes' anemometer, this will make water or mercury contained in a cup revolving on the axle of the anemometer rise at the circumference of the cup, and measure the same pressure by its change of level. A centrifugal pump, elevating the liquid from one large trough or cistern to another, takes the place in this case of the simple bent water-tube of Lind's wind-gauge. To translate this elevation into its corresponding wind-velocity requires a calculation by the rule that it bears a constant ratio to the square of that velocity. If now a pendulum-bob floats on the lifted fluid surface in the trough, like a cork buoy, the pendulum-stem being vertical when there is no elevation, or when no pressure and speed are being indicated, and if the stem's upper end is socketed in this position so that the pendulum can turn round it without rising, an elevation of the liquid in the trough makes the pendulum to slope outwards, and its point to depart from its lowest vertical position to a horizontal distance from it, whose square is, by a simple geometrical property of a circle, proportional to the rise in height for all movements of the bob which are small in their extent compared with the pendulum-stem's length.

The problem of effecting this change of measurement from one equivalent way of expressing an air-current's rapidity or force of stream to the other, by some commodious mechanical means exact enough to be for all ordinary purposes a substitute for calculation, had some time ago been suggested to Prof. Herschel as a great *desideratum* by Mr. G. M. Capell, and he had partially succeeded with a square-cornered triangle on a drawing-board in meeting the requirements. But the present ingenious use of the lateral displacement of a floating pendulum in a circle had, when shown to him by Mr. Dines, quite surprised him by its perfect simplicity and fitness. In the neat state exhibited of its now finished adaptation to a revolving anemometer, he felt sure that its inventor and the skilful constructor of the instrument had succeeded together in producing a kind of actual indicator of varying velocity, which would hereafter, without doubt, prove to be of the greatest service in the study of anemometry.

Mr. W. H. DINES, in reply, said that he had only gone into the question of the factor of the Kew Standard anemometer, and therefore could not say much about the smaller kinds; but he believed that all sizes were more or less dependent upon the character of the wind. He would not go so far as to say that the factor might in some instances be double what it was in others, but he thought that there was still an uncertainty about it to the amount of 30 per cent. Mr. Curtis had remarked that the cups took up the velocity very quickly. No doubt they did so, but unfortunately they did not lose it with equal quickness, and it was this that made the instrument so unreliable. He had tried a good many anemometers, both of the Robinson and of the air-meter type, and also his own Helicoid anemometer. With regard to the latter, as the results were given in the preceding report, he would say nothing further about it. He had found that, having once tested an air meter, it was possible to predict the result of a second trial to within one or, at most, two per cent., and hence he considered the air-meter type of anemometer to be the best. He agreed with Professor Herschel that since the pressure varied as the square of the velocity, the velocity could always be found when the pressure was known. He liked the Robinson anemometer on account of its simplicity; but he thought no instrument of that type could be depended upon to give the real mean velocity, because there was no doubt but that they all took up the proper velocity more quickly than they lost it. No modification of the factor could remedy this, because the departure from the mean was greater for a gusty than for a comparatively steady wind. This conclusion was the same as that which had been deduced from the American experiments, but it had been reached quite independently. He certainly thought that the factor 3 should be altered, or at least that the wording of the Kew certificate—viz. "of the true amount"—should be changed, for it seemed to him absurd to continue calling the records of the Kew Standard "the true amount" when everyone acquainted with the matter knew well that they were nothing of the kind.

ON TESTING ANEMOMETERS.

By W. H. DINES, B.A., F.R.Met.Soc.

[Received October 18th—Read December 18th, 1889.]

THERE are, theoretically, two plans on which an anemometer may be tested, and the constants of the instrument determined, but both present considerable practical difficulties. The first is to make a current of air pass over the instrument at a known velocity; but since there is no perfectly correct method of measuring the velocity, the only way is to place the instrument in a tube and make a given volume of air, for example, the contents of a gas-holder, pass through the tube in a given time. This plan, however, is not satisfactory, for the air undoubtedly moves faster at the centre than at the sides of the tube, where it is impeded by skin friction, and also, unless a tube of very large cross section were employed, the instrument would occupy an appreciable portion of the space, and the calculation of the velocity would be rendered almost impossible.

The second plan is to move the instrument itself at a known rate through still air, and if only still air could be obtained, there would be no further difficulty. A little consideration shows that it cannot matter whether the air pass over the instrument, or the instrument itself be moved through the air. In either case we obtain the velocity of the air relatively to the instrument, and nothing more. In the first the instrument is only fixed relatively to the earth's surface, and if it were possible to suppose a difference between the two cases, it would be necessary to go still further, and say that the motion of the earth itself must affect the result.

In consequence of the expense which would be incurred by arrangements suitable for moving an anemometer in a straight line, almost all experiments on the subject have been made with circular motion. Provided that the radius of the circle be large compared with the size of the instrument, the circular motion itself is perhaps unobjectionable; but, unfortunately, two difficulties are introduced by it. The force required to retain the instrument in its circular path being very considerable, special care is necessary in the mounting, and after every precaution has been taken, the pressure of the moving parts of the instrument on the bearings, and therefore the friction is undoubtedly greater than it would otherwise be. This must alter the result, although the extent to which it does so is probably slight.

The second difficulty is that the instrument is constantly moving over the same spot at short intervals of time, and consequently some of its motion is imparted to the air, which soon ceases to be perfectly still. This is particularly the case if the experiments are conducted in a closed building, and if the instrument is of any size or the speed at all great, the eddy set up

is very considerable. This second trouble is almost avoided by working in the open air, but it is, unfortunately, replaced by another. It is very seldom indeed that it is absolutely calm, and possibly during such a calm the same sort of eddy that occurs indoors might be set up by a large instrument, such as the Kew pattern anemometer, moving at a high speed. For certain kinds of instruments, however, the natural wind does not matter so much, but the difficulty of knowing how to allow for it in the case of the Robinson anemometer is very great. There are three reasons for this. In the first case the wind never blows uniformly, and any correction based on the assumption that the wind is steady is not correct; secondly, if the anemometer does not register the same percentage for different velocities a further difficulty is introduced; but perhaps this need not be considered, unless the rate of the natural wind be nearly equal to that of the instrument. The other difficulty seems to belong especially to the Robinson anemometer. If this instrument be exposed to a wind, the velocity of which varies within wide limits at short intervals of time, it records a higher rate than it would do if exposed to a steady wind of the same mean velocity. The instrument, when in actual use, is exposed to a variable velocity, so that there is a certain advantage in trying experiments under circumstances which do, to some extent, agree with the actual conditions.

Suppose an anemometer to be moved in a circle at a rate of 40 miles an hour, and that the wind is blowing at 8 miles an hour, it is clear that the relative rate of the anemometer ranges from 32 to 48 miles an hour, it being 32 in the part of the circle in which it is moving with the wind and 48 in the opposite part. Also it may be shown that the mean relative velocity is very nearly equal to $40\frac{2}{3}$ miles per hour. An ordinary wind, the mean velocity of which is about 40 miles per hour, probably varies between far greater limits; but at present we know little about the extent or frequency of the variations, so that when we have found the constants of the Robinson anemometer for a uniform speed we shall still be uncertain about the results when the speed is variable. Still, a wind varying between the limits of 32 to 48 miles per hour is no doubt nearer to what occurs in practice than a perfectly uniform rate of 40 miles per hour would be.

If we make three assumptions, there is no difficulty in finding the corrections which should be applied in the case of experiments made in the open air while there is some natural wind. Suppose that u is the rate of the instrument, and v that of the wind; also assume (1) that the wind is blowing steadily; (2) that the registration of the instrument is practically uniform for all rates lying between $u + v$ and $u - v$; and (3) that the instrument records the mean velocity to which it is exposed. Then if $\frac{v}{u}$ is so small that $\left(\frac{v}{u}\right)^4$ and higher powers may be neglected, the velocity recorded by the anemometer should be $u + \frac{1}{2} \left(\frac{v}{u}\right)^2 u$. In the hypothetical case given above—namely, $u = 40$ and $v = 8$ —this gives a correction of only 1 per

cent., so that if the three assumptions made above were allowable, a slight or even moderate breeze blowing during the experiment would not be of much consequence.

There is one other point which should be considered. A Robinson anemometer is always placed with its axis vertical, and when in that position its record of the velocity is quite independent of the direction of the wind. When experiments are made with a whirling machine, and the axis of the instrument is vertical—that is, parallel to the axis of the whirler—the inner cup has a much smaller velocity than the outer, and consequently experiments so made, and taken alone, are not of the least value. It is usual to reverse the position of the cups, so that they shall turn in the opposite direction, and then make another set of experiments. Using the number of turns of the cups relatively to the whirler—that is, the sum of the numbers of turns of both, when both turn in the same direction, and the difference when they turn in opposite directions, and taking the mean of the two sets—the final result must be very nearly correct. The trouble of making a double set of experiments may, however, be avoided by placing the axis parallel to the long arm of the whirler. In this position, assuming that the air is still, the direction of motion is parallel to the plane of the cups; and although in practice an anemometer is never placed in this position, yet, when experimenting with a whirling machine, it represents the actual conditions more nearly than the vertical position would do. So long as the plane of the cups is parallel to the direction of the wind, it cannot matter in what particular position the instrument is placed, the only possible effect being a slight alteration of the friction. But in testing an anemometer upon a whirling machine, any slight alteration in the friction which may occur on account of the radial position of the axis is very trifling when compared with the alteration which is inevitably produced by the effect of the centrifugal force.

ON THE RAINFALL OF THE RIVIERA.

By G. J. SYMONS, F.R.S., Secretary.

(Plates II.-IV.)

[Received September 13th.—Read December 16th, 1889.]

REQUIRING information respecting the rainfall of one of the towns on the Mediterranean coast of the Department of Alpes Maritimes, I was very much surprised to find how little was said about it even in the best books upon Cannes, Mentone, Nice, and the other towns on that lovely coast.

I was, therefore, obliged to collect what I could, and having done so it occurred to me that this collected material should be rendered generally accessible. This is the more desirable because Lord Brougham and Vaux has been kind enough to send me a complete copy of the very important and unbroken record kept at his Villa from 1865 to the end of 1888, and which has hitherto been unpublished. Besides it, I have collected observations from various sources, especially from the volumes *Pluies en France*, published by the French Meteorological Office, and from Professor Raulin's *Observations Pluviométriques*.

In order to utilise the records which are themselves too short to afford trustworthy means, it has been necessary to choose some standard stations, and there are four at each of which the record is perfect for the ten years 1877 to 1886. The totals at each of these stations have been converted into their ratios to the mean of the ten years, and the average ratio for each year has been assumed to represent the percentage by which each individual year was wetter or drier than the ten year mean. These values are given in Table I., and they are also plotted on Plate II., in order to show by their close general accordance how safe is this mode of calculation.

In Tables II. to X. is given the monthly and annual fall at every station whence I could procure it, and those values, uncorrected when they embrace at least ten years, and corrected by the ratios in Table I. where they are for less than ten years, give the following approximate averages:—

APPROXIMATE MEAN ANNUAL RAINFALL, AT STATIONS ON THE RIVIERA.

	Inches.
Cannes—Villa Louise Eléonore, 1865 to 1888, 24 years...	81·89
„ „ „ „ 1877 to 1886, 10 years...	80·59
„ ? „ „ 1877, 1 year ...	24·6
„ Ponts et Chaussées, 1880 to 1886, 7 years...	80·6
„ M. Reynaud, 1888 & 1884, 2 years...	80·0

APPROXIMATE MEAN ANNUAL RAINFALL AT STATIONS ON THE RIVIERA.

Continued.

		Inches.
Antibes—La Garoupe (Lighth.)	1877 to 1886, 10 years...	28·67
Nice—École Normale,	1877 to 1886, 10 years...	31·22
„ Port,	1880, 1 year ...	29·0
„ Observatory (1116 ft.),	1883 to 1886, 4 years...	26·7
Villefranche (Lighthouse),	1877 to 1886, 10 years...	27·52
Monaco,	1880 & 1881, 2 years...	22·8

Besides the above, I have found incomplete records and several mean values which afford the following results :—

		Inches.
Nice (quoted by Smollett),	1849 to 1878, 30 years ..	32·2
„ (quoted by Roubadi),	...	25·8
„ (quoted by Raulin),	1829-31 & 1838-42 imp. ...	29·6
„ („ „ „),	1870 to 1874, 5 years...	35·2
„ Military Hospital,	1864 to 1873 imp. ...	36·8
„ École Normale,	1865 to 1874 imp. ...	32·8

Mentone—Various values ranging from 28·7 to 32·0.

The positions of these several towns are shown on the sketch map, Plate III.

The values given above differ so greatly for the same town as to leave one in doubt which to accept, but the impression left upon my mind is that the total annual fall along the Riviera from Cannes to San Remo is about 81 inches, and that any difference between the several towns has yet to be proved. The maps of Keith Johnston, of Krümmel, and of Angot all show a rainfall increasing from West to East. This may be true inland, but there is certainly no distinct evidence of it in any observations on the coast.

Monthly Fall.

The information upon this subject is very accordant. There is usually about 2 inches a month up to and including May, then there are three dry summer months—June, July, and August—followed by three with large totals (4 inches or 5 inches each), and then December drops to about the average of the early months of the year.

These details will be better grasped by reference to Plate IV.

There is, however, an anomaly with respect to the fifth curve, that representing the observations from Nice for 1849-78, viz. that though the shape of the curve is very similar to the other four, all the features occur a month earlier. I have not the original, and cannot therefore say whether it is true, or due to an error in copying. Each seems to be equally improbable.

Rainy Days.

Days with less than 0·04 inch are, I think, rarely recorded in that district, and, with the generally bright sun and dry air, such falls would be of little importance. Still, when we find that the total of days of rain on the Riviera

is about 65 per annum instead of from twice to three times that number, as recorded in England, we may perhaps derive some comfort from remembering that if a British observer were to reside there he would probably pick up sundry little showers which now escape notice. He might perhaps turn the 65 into 75, but even if so the total remains very small.

Heavy Falls.

Evidently with more rain than London, and less than half as many days with rain, the falls individually must be greater, and so they are; in London falls of three inches in 24 hours are very scarce, but not so on the Riviera—there it either rains heavily, or it is fine. If it rains, the probability is that there will be half an inch before it is over—and as far as I can judge, it seems that the characteristics of the heavy falls on that coast are, *not* such short and intense rains as we get during thunderstorms in England, but persistent heavy rains, say 0·5 in. per hour for 8, 10, or 12 successive hours—that was the character of one of the great rains of the decade 1877-86, viz. that of October 26th, 1886, when I happened to be at Cannes and able to watch it. That day of the year (by-the-bye it is very near the anniversary of our Royal Charter storm) is frequently very wet. The late Lord Brougham informed me that at his Villa on October 27th, 1882, the fall between 2.30 p.m. and midnight was 4·50 inches, or half an inch an hour for 9½ successive hours. In the same letter his Lordship said that he had once measured “an inch in twenty minutes.” That was certainly an exceptional fall, but much more remarkable cases are on record during the last 10 years in the British Isles, the greatest being 1·78 in. in 20 minutes during the great thunderstorm of June 28rd, 1878, at Camden Square.

I ought perhaps to apologise for the sketchy nature of this paper, but if nothing is to be done unless it can be done perfectly, very little will be done. And no one will be more pleased than I shall be, if this paper is shortly superseded by a better one.

P.S.—There was one other record of which I knew when writing the foregoing paper, but of which I could say nothing, because I had not the values. I refer to the record kept from 1866 to the present time by the talented author of *Cannes et son Climat* and other works, Dr. De Valcourt. He has been so good as to prepare a table of the monthly and annual rainfall, and the number of days, which I hope that the Council will allow me to add to my paper, as greatly increasing its value. The mean rainfall agrees closely with that reported by Lord Brougham, viz. 81 inches, and the average number of days with rain is 70, thus agreeing closely with the other stations, which give about 65. The wettest year was 1872, 66·09 inches, the driest 1877, 17·88 inches. The wettest month, October 1872, with 20·59 inches, and the wettest day, October 27th, 1882, 5·48 ins. in 8 hours; this being the day on which Lord Brougham recorded 4·50 ins.

TABLE I.

RATIOS OF EACH YEAR 1877-1886 TO THE MEAN OF THE WHOLE PERIOD.

Year.	Cannes. Villa Louise Eléonore.	Antibes. La Garoupe.	Nice. École Normale.	Villefranche.	Adopted Mean.
1877	67	87	88	107	87
1878	75	92	106	117	98
1879	145	136	116	124	130
1880	86	78	81	80	81
1881	115	112	102	112	110
1882	103	94	115	98	103
1883	122	103	107	100	108
1884	67	60	65	49	60
1885	106	112	113	101	108
1886	114	126	107	112	115
Mean ..	100	100	100	100	100

TABLE II.—RAINFALL at Cannes (Villa Louise Eléonore.)

Year.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
January	1'48	'09	7'84	1'48	1'09	1'21	2'21	6'19	'78	1'90	'12	'98	1'98
Feb. ..	1'40	1'75	4'14	'58	1'11	5'55	1'42	2'31	2'68	3'88	'55	'00	'00
March	'23	8'15	4'40	3'79	4'00	2'13	'76	6'19	4'45	1'37	'12	3'00	3'68
April ..	2'15	4'43	'66	1'32	'66	'92	'70	4'00	3'72	3'87	3'53	3'87	2'98
May ..	'70	2'85	1'52	'22	2'71	'00	4'44	3'04	2'52	'35	'53	1'42	3'04
June ..	'27	'31	'00	'11	'92	2'18	2'59	'00	'39	1'18	4'51	'95	'45
July ..	1'09	'53	'08	'70	'00	'82	'00	2'50	'00	'27	'45	'06	'24
August	1'39	1'09	1'16	'44	'20	3'84	'00	'00	'00	'00	1'20	1'38	'07
Sept. ..	'15	3'71	'47	8'06	2'06	'00	4'72	'23	'65	2'71	'56	'12	'09
October	11'50	7'23	2'90	7'52	1'19	2'83	'36	16'90	8'11	4'44	4'97	4'02	2'82
Nov. ..	4'23	'06	2'00	5'87	7'30	8'51	10'28	4'13	7'95	'50	'30	5'48	5'07
Dec. ..	5'58	1'65	4'23	2'09	3'49	'44	6'10	13'91	'00	2'92	1'76	5'96	'16
Totals	30'17	31'85	29'40	32'18	24'73	28'43	33'58	59'40	31'25	23'39	18'60	27'24	20'58
Max. fall	2'95	6'20	2'50	2'16	7'30	3'88	5'00	3'90	2'92	2'45	3'60	2'40	2'60
Days of rain	63	58	54	61	39	37	50	62	43	32	32	43	29
Year.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.	Mean 24 yrs.	
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
January ..	'00	4'76	'35	5'42	2'19	10'42	'91	4'31	5'45	4'72	1'02	2'79	
February ..	'00	3'58	3'28	2'98	1'03	3'32	1'09	5'45	2'38	1'28	2'58	2'18	
March ..	1'34	7'79	'12	1'00	1'65	6'40	1'27	'97	2'08	'88	6'88	3'03	
April ..	2'45	8'71	2'26	1'38	'94	5'31	3'77	2'75	3'42	4'12	1'94	2'91	
May ..	1'26	6'96	2'99	4'03	3'19	2'19	1'51	1'13	1'20	'49	'16	2'02	
June ..	1'71	'32	3'04	'64	'00	'94	2'91	4'35	'66	1'85	2'22	1'35	
July ..	'00	'34	'00	'00	'15	'52	'14	'00	'10	1'01	'43	'39	
August ..	1'60	'40	2'88	3'18	'10	'12	'16	1'01	2'10	'15	3'38	1'08	
September ..	'98	6'87	2'27	4'00	6'25	3'10	1'90	1'10	1'62	'79	1'60	2'25	
October ..	3'06	'63	'66	5'85	12'34	2'39	2'32	6'30	7'91	4'08	'85	5'05	
November ..	6'71	3'22	8'18	3'59	1'00	1'90	'40	4'41	6'41	12'56	15'27	5'22	
December ..	3'91	'62	'20	3'15	2'72	'77	4'13	'56	1'56	3'87	17'08	3'62	
Totals ..	23'02	44'20	26'23	35'22	31'56	37'38	20'51	32'34	34'89	35'80	53'41	31'89	
Max. fall ..	1'60	3'10	3'40	3'10	4'70	3'20	2'00	3'60	3'00	3'05	5'80		
Days of rain	49	59	43	60	42	53	44	50	61	49	51		

III.

IV.

V.

Year.	Cannes. Above Sea 10 ft.	Cannes (Ponts et Chaussées). Above Sea 16 ft.							Cannes (Reynaud). Above Sea 49 ft.		
		1877.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1883.	1884.	1885.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
January	1'50	'35	5'59	1'22	7'76	'59	2'64	4'88	4'57	'79	2'13
February	'04	3'03	2'05	1'10	3'42	1'10	4'13	2'56	5'55	'67	3'78
March	3'98	'16	'52	1'54	7'28	1'81	1'14	1'81	6'02	1'89	'59
April	2'76	3'98	1'57	1'06	4'45	3'58	3'31	1'18	4'02	3'19	2'60
May	3'50	1'89	4'10	2'13	1'93	1'85	1'34	1'57	1'89	1'77	1'50
June	'63	1'97	'59	'00	1'22	2'72	5'39	'91	'98	2'76	4'88
July	'32	'00	'00	'39	'71	'16	'00	'28	'71	'16	'00
August	'08	2'52	3'70	'16	'16	'12	1'77	1'73	'16	'08	..
September ..	'12	3'15	1'85	4'21	3'74	2'01	2'32	1'46	3'15	1'34	..
October	1'38	1'22	5'91	11'06	2'36	2'40	8'07	9'65	2'01	2'40	8'94
November ..	6'81	6'02	3'66	'71	1'77	'39	4'06	6'22	1'89	'39	3'47
December	'28	1'69	2'64	2'44	'71	3'66	'71	2'48	'63	3'31	'39
Totals	21'40	25'98	32'18	26'02	35'51	20'39	34'88	34'73	31'58	18'75	..

Max. Fall..... 2'32 2'72 2'05 5'47 2'52 1'89 3'94 2'28

Days of Rain .. 56 70 58 74 69

VI.—ANTIBES (LA GAROUPPE). Above Sea 266 feet.

Year.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	Mean.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
January ...	1'81	'55	3'62	'28	6'54	2'99	4'61	'67	3'11	4'33	2'85
February ..	'00	'04	5'35	4'10	1'06	'63	4'57	'79	3'66	2'13	2'23
March	4'72	1'06	4'45	'08	1'14	'98	5'12	1'85	'71	1'73	2'18
April	2'44	2'79	6'42	1'89	1'18	'32	3'82	3'11	1'97	2'40	2'63
May	3'07	1'26	6'06	1'81	5'39	1'50	1'58	1'46	'94	1'77	2'49
June	'24	1'34	'16	1'58	'71	'00	1'18	1'50	6'65	1'10	1'43
July	'55	1'18	'24	'00	'00	'28	'43	'00	'16	'08	'29
August	'00	1'06	'32	1'89	3'15	'04	'35	'28	'55	1'38	'90
September ..	'51	1'85	7'91	3'03	5'16	5'75	4'25	2'20	5'00	'94	3'66
October	4'02	4'17	'83	1'50	3'70	10'98	1'69	2'21	4'68	9'61	4'34
November ..	7'36	7'48	1'50	5'20	2'95	'79	(1'38)	'67	4'21	7'80	3'93
December ..	'35	3'50	2'05	1'02	1'26	2'56	'59	2'60	'35	2'87	1'72
Totals	25'07	26'28	38'91	22'38	32'24	26'82	(29'57)	17'34	31'99	36'14	28'67

Max. Fall.... 3'62 1'18 3'50 2'20 3'19 5'00 1'61 5'00

Days of Rain 52 .. 54 61 ..

VII.—NICE. ÉCOLE NORMALE. Above Sea 56 feet.

Year.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	Mean.
January	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Feb. . .	1'54	'71	1'65	'00	5'79	1'06	4'88	'71	2'68	5'51	2'45
March ..	'00	'00	4'41	3'43	1'38	'95	4'57	'75	7'91	1'50	2'49
April ..	5'83	1'73	6'61	'20	'75	2'13	3'66	2'72	1'02	1'65	2'63
May....	3'47	(2'95)	(6'00)	3'58	1'73	1'10	3'90	3'31	5'43	3'23	3'47
June ..	3'27	1'93	8'03	1'50	3'27	3'23	3'11	1'06	1'73	2'09	2'92
July....	1'34	'91	'00	(2'28)	1'42	'08	3'19	2'60	2'05	'71	1'46
August	'63	'08	'43	'08	'00	'51	'98	'00	20	'12	'30
Sept. . .	'04	('98)	'71	2'79	2'72	'16	'43	2'20	'75	1'42	1'22
October	'47	(3'94)	4'57	3'19	4'13	7'13	1'77	3'03	1'30	1'26	3'08
Nov.....	3'50	9'65	'67	2'01	4'13	14'96	3'86	1'06	7'72	7'09	5'47
Dec.....	7'05	5'71	1'30	(4'72)	5'59	1'65	2'60	'59	3'98	5'55	3'87
Totals....	'28	4'49	1'57	(1'42)	1'06	2'99	'59	2'20	'59	3'39	1'86
Totals ..	27'42	(33'08)	(35'95)	(25'20)	31'97	35'95	33'54	20'22	35'36	33'52	31'22

Max. Fall	2.91	4.13	1.93	2.36	3.07	<div> <div>Oct.</div> <div>28</div> <div>5.71</div> <div>Oct.</div> <div>12</div> <div>5.16</div> </div>	2.79
Days of Rain						52	74

VIII.

IX.

Year.	Nice (Port) Above Sea 30 ft.	Nice (Observatoire), Above Sea 1116 ft.				
	1880.	1883.	1884.	1885.	1886.	
	In.	In.	In.	In.	In.	
January	16	3'62	('79)	2'17	6'58	
February	2'36	1'42	'83	5'83	1'50	
March	'00	4'02	2'28	1'06	1'38	
April	3'19	2'87	2'48	3'54	2'99	
May	1'54	2'24	'94	1'46	2'24	
June	2'28	2'36	3 62	2'76	'94	
July ..	'08	'20	'24	'00	'28	
August	2'16	'43	'75	'98	'75	
September	3'07	'55	2'01	'75	1'14	
October	2'13	'39	1'10	10'04	6'77	
November	5'04	'75	'39	3'82	5'63	
December	1'50	'12	2'44	'83	3'98	
Totals	23'51	18'97	(17'87)	33'24	34'18	

Max. Fall
Days of Rain

57	4'25 109	2'76
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X.

XI.

Year.	Villefranche, Above Sea 207 ft.											Monaco.	
	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	Mean.	1880.	1881.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
January	1'50	'71	1'97	'12	5'28	'91	4'69	'52	2'17	4'96	2'28	'20	5'63
February	'00	'04	3'19	2'79	'63	'43	4'02	1'10	4'53	1'38	1'81	3'27	'24
March ..	7'44	1'26	5'43	'08	1'61	2'60	3'94	1'73	'87	1'50	2'65	'04	1'10
April ..	2'91	3'07	6'81	3'54	1'54	'35	3'62	2'95	2'60	2'32	2'97	3'98	2'13
May	2'99	3'50	7'52	1'34	3'15	2'01	2'48	'47	1'65	1'58	2'67	1'69	1'81
June ...	'35	1'22	'12	1'97	'35	'00	1'50	2'17	1'77	1'06	1'05	1'93	'43
July	'32	'00	'08	'00	'00	'12	'16	'00	'00	'00	0'07	'00	'00
Aug.	'00	'91	'08	2'01	1'61	'12	'55	'20	'55	'75	'68	2'60	'75
Sept. ...	1'18	4'45	4'45	2'56	4'68	5'75	1'73	1'30	2'13	1'50	2'97	3'23	1'30
October	3'94	6'58	1'06	2'13	5'75	11'18	2'87	1'02	6'06	5'24	4'58	3'35	1'97
Nov. ...	8'54	6'38	1'42	4'13	5'39	1'06	2'09	'67	4'61	6'50	4'08	4'17	'43
Dec.	'16	3'98	1'89	1'34	'83	2'56	'00	'42	'91	4'02	1'71	1'50	1'06
Totals ..	29'33	32'10	34'02	22'01	30'82	27'09	27'65	13'55	27'85	30'81	27'52	25'96	16'85
Max. Fall	3'31	2'95	1'97	1'42	3'15	4'80	1'65		2'01			2'01	1'14
Days of													
Rain						49	78	53	75	81			

Summary of Rainfall Observations at Cannes, 1866-1888.

By M. LE DR. DE VALCOURT.

1866-87, VILLA CLARA. 1888 VILLA HAUTEVIVE.

Year.	1866.		1867.		1868.		1869.		1870.		1871.		1872.		1873.		
	Days.	Amount.	Days.	Amount.	Days.	Amount.	Days.	Amount.	Days.	Amount.	Days.	Amount.	Days.	Amount.	Days.	Amount.	
January ..	4	In. '89	11	6'53	3	In. '87	5	In. '10	8	In. '46	9	In. '64	16	In. '26	13	In. '66	
February ..	8	1'33	7	4'52	1	'57	5	1'65	15	6'60	1	'02	7	2'60	6	2'38	
March	14	8'15	12	4'11	5	3'92	16	4'70	5	2'26	8	1'16	7	5'59	8	3'28	
April	8	5'04	4	'56	4	'86	5	'94	1	'83	2	'23	11	6'19	5	3'87	
May	7	3'38	5	1'67	8	'61	..	0	'00	8	4'60	9	3'35	4	1'87		
June	4	'82	..	3	3'70	7	3'56	0	'00	7	'48		
July	6	'61	..	2	1'50	3	'17	5	1'48	0	'00		
August	4	'82	..	4	'46	2	'18	2	'31	0	'00		
September	8	4'21	1	'90	9	9'75	..	2	'94	7	5'94	1	'20	3	'75		
October	7	2'65	9	8'81	..	2	2'05	4	'99	19	20'59	12	8'42		
November	2	'28	7	2'79	10	5'54	5	2'41	13	6'46	13	10'16	7	4'00	9	7'68	
December ..	5	2'04	7	3'75	11	2'32	9	6'14	16	5'28	5	4'37	14	13'52	2	'11	
Yearly Total ..	..	..	..	..	74	35'50	..	..	71	32'54	69	36'02	98	66'09	69	30'50

SUMMARY OF RAINFALL OBSERVATIONS AT CANNES, 1866-1888.—*Continued.*

Year.	1874.		1875.		1876.		1877.		1878.		1879.		1880.		1881.	
	Days.	Amount.	Days.	Amount.	Days.	Amount.	Days.	Amount.	Days.	Amount.	Days.	Amount.	Days.	Amount.	Days.	Amount.
		In.		In.		In.		In.		In.		In.		In.		In.
January ..	2	1'79	3	'43	10	2'81	4	1'47	3	'43	8	3'83	2	'36	17	5'57
February ..	6	5'18	8	2'76	2	'42	1	'05	1	'06	12	2'81	7	3'02	6	2'04
March	4	1'00	5	'78	8	2'64	12	3'94	6	1'56	13	6'37	2	'16	3	'51
April	4	4'92	8	3'21	12	3'79	9	2'75	8	3'27	14	6'65	9	3'98	8	1'57
May	4	'97	3	'62	5	2'15	7	3'54	7	1'52	10	5'83	6	1'89	7	4'12
June	2	'98	11	3'21	7	1'52	4	'63	6	1'79	1	'32	5	1'96	3	'59
July	0	'00	4	'38	2	'12	2	'29	1	'01	1	'24	0	'00	0	'00
August	1	'31	2	1'40	4	1'06	1	'08	1	1'78	1	'55	7	2'52	4	3'71
September...	5	2'86	2	'18	1	'13	3	'13	2	1'08	8	7'81	5	3'15	5	2'56
October	7	4'98	9	6'09	7	3'52	5	1'37	9	4'43	4	'55	5	1'23	9	5'12
November ..	4	'76	7	'67	8	2'85	7	2'87	13	6'42	9	3'01	9	6'04	6	3'63
December ..	8	2'13	7	1'69	11	6'57	4	'26	11	1'84	3	1'64	4	'46	7	2'63
Yearly Total	47	25'88	69	21'42	77	27'58	59	17'38	68	24'19	84	39'61	61	24'77	75	32'05

Year.	1882.		1883.		1884.		1885.		1886.		1887.		1888.	
	Days.	Amount.	Days.	Amount.	Days.	Amount.	Days.	Amount.	Days.	Amount.	Days.	Amount.	Days.	Amount.
		In.		In.		In.		In.		In.		In.		In.
January	2	1'22	11	7'76	1	'59	7	2'63	8	4'88	6	4'14	3	'68
February ..	1	1'09	7	3'54	6	1'12	6	4'14	8	2'55	5	1'93	10	3'69
March	4	1'55	9	3'33	4	1'82	9	1'13	5	1'80	5	1'68	13	5'79
April	6	1'05	9	4'47	10	3'57	9	3'30	10	2'55	4	2'94	7	2'25
May	7	2'13	6	1'94	4	1'83	4	1'34	3	1'56	4	'65	5	'15
June	0	'00	5	1'20	8	2'70	4	4'98	6	'91	3	1'00	4	1'71
July	5	'37	2	'70	3	'15	0	'00	3	'27	4	1'02	5	2'13
August ...	2	'16	1	'14	1	'10	5	1'76	4	1'73	3	'38	3	1'18
September	8	4'23	8	3'73	7	2'02	4	2'32	6	1'47	3	'67	5	1'46
October	9	11'08	3	2'38	4	2'35	10	8'07	12	9'64	6	3'59	4	1'15
November ..	2	'72	4	1'76	1	'41	9	4'05	11	6'22	15	10'16	11	11'17
December ..	9	2'42	5	'55	5	3'60	2	'71	8	2'50	5	3'04	9	11'47
Yearly Total	55	26'02	70	31'50	54	20'26	69	34'43	84	36'08	63	31'20	79	42'83

Mean 1868, 1870-88 = 20 years 31'79 ins. Mean 1877-86 = 10 years 28'63 ins.

Height of Rain Gauge above the ground 3 ft. 3 in.
 " " " sea level 99 0
 Diameter " 0 10

The gauge was in an open garden, and not at all sheltered by trees or walls.
 Babinet's Rain Gauge at the same altitude above sea at both places.

DISCUSSION.

The PRESIDENT (Dr. Marcet) remarked that Mr. Symons was exceedingly modest in describing his paper as sketchy, for it was really a useful and valuable communication. He had spent nine successive winters in the Riviera, three at Nice, and six at Cannes, and could confirm what had been said respecting the rainfall being heavier there than in our own country. The wet weather always came with the easterly wind, and frequently quite suddenly. The north-westerly wind, or "Mistral," was the fine weather wind, and he had seen a very cloudy sky become clear within half an hour of the time when the "Mistral" commenced to blow. He did not know any place where the changes of weather

were so rapid as in the Riviera. He was not in the Riviera when the heavy rainfall in 1882, mentioned by Mr. Symons, was experienced; but he heard about it, and knew that it occasioned very disastrous floods. Fortunately such experiences were rare, and any fear of such a phenomenal rainfall need not deter anyone from wintering in the locality.

Mr. TRIPP remarked that there were two stations on this coast—Marseilles at the western end and Genoa at the eastern end—at which long series of rainfall observations had been made. He had forgotten the actual figures, but it appeared to be a characteristic feature of seaports to have a high range of fall; and he recollected that at these two stations the total for the wettest year was more than twice the average yearly total; and at St. Bernard in the back country at a great elevation the total for the wettest year was nearly three times the mean of a long series of years.

Mr. BREWIN pointed out that the position of Monaco possibly accounted for its getting less rainfall than the other towns in the Riviera, as it projected further from the mountains, and so was less under their influence.

Mr. HARRIES remarked, concerning the exceptionally heavy fall of an inch in twenty minutes at Nice, that heavier falls had been reported in France. On June 22nd, 1889, 1·73 inches fell in 20 minutes at Rochefort, and on the previous day 1·6 inches in 15 minutes at Trampot. On June 6th, 1888, at Frain, 1·65 inches was recorded in 15 minutes; at Toulouse in April, 1841, 1·5 inches; and in March, 1844, 1·58 inches fell in 15 minutes.

Mr. SOUTHALL observed that the greatest falls seemed to occur in the autumn months in the Riviera, whereas in the British Isles the spring months were those in which the heaviest falls were experienced.

Mr. SYMONS, in reply, said that the heavy rainfall at Cannes in October, 1882, was recorded at two stations, and the two returns were consistent with each other. The rainfall in the latter part of the year was heavy, and there were many cases of from 10 to 20 inches in a month.

REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1889.

By EDWARD MAWLEY, F.R.MET.SOC., F.R.H.S.

[Read December 18th, 1889.]

For the purposes of this Report I have divided the British Isles into districts differing very slightly from those adopted by the Meteorological Office. For greater clearness these districts have, however, been considered in a reversed order, beginning with the warmer parts of these Islands and proceeding irregularly upwards towards the colder. In order to prevent confusion, the different districts are here indicated by capital letters instead of figures.

The following is the list of stations and observers for the past year (p. 58).

The only station not included in last year's report is that at the Horticultural College, Swanley, Kent. Ireland South (G.) and Scotland East (J.) and North (K.) are altogether unrepresented.

District.	Station.	County.	Observer.
A.	Babbacombe (Torquay)	Devon	E. E. Glyde
"	Tiverton	Devon	Miss M. E. Gill
"	Westward Ho (Bideford)	Devon	H. A. Evans
"	Usk	Monmouth	C. Mostyn
"	Wells	Somerset	The Misses Livett
B.	Killarney	Co. Kerry	Ven. Archdeacon Wynne, D.D.
"	Wicklow	Co. Wicklow	The Misses Wynne
C.	Pennington (Lymington)	Hants	Miss E. S. Lomer
"	Buckhorn Weston (Wincanton)	Dorset	Miss H. K. H. D'Aeth
"	Salisbury	Wilts	W. Hussey and E. J. Tatum
"	Swanley (Dartford)	Kent	C. A. Hooper
"	Ealing	Middlesex	A. Belt
D.	Oxford	Oxford	F. A. Bellamy
"	Northampton	Northampton	H. N. Dixon
"	Thurcaston (Leicester)	Leicester	Rev. T. A. Preston, M.A.
"	Belton (Grantham)	Lincoln	Miss F. H. Woolward
"	Macclesfield	Cheshire	John Dale
"	Hodsock (Worksop)	Nottingham	Miss A. Mellish
E.	Tacolneston (Wymondham)	Norfolk	Miss E. J. Barrow
F.	Settle	{ Yorkshire (West Riding)	S. S. Burlingham and The Misses Thompson
H.	Tynron	Dumfries	James Shaw
I.	Durham	Durham	H. J. Carpenter

The Autumn of 1888.

The first two months of this season were very cold, dry and sunny, whereas November, on the other hand, proved singularly warm, wet and sunless. Early in October there occurred a series of frosts of exceptional severity for the time of year, which, especially in the Midland counties, did considerable damage to the foliage of trees and gave a sharp check to vegetation generally. Owing to the same cause, the number of wild flowers was after this time very limited, while the autumnal tints were poor and of brief duration. In more favoured localities, however, certain summer-flowering plants came into blossom a second time, and here and there a few spring flowers were also to be seen. This was a very unfavourable season for ripening the wood of fruit and other trees.

Observers' Notes.

OCTOBER, 1888.—*Ealing* (C.). 14th. Last swallow seen. *Settle* (F.). 10th. A wild rose was found in full flower on one of the hedges near here.

NOVEMBER.—*Pennington* (C.). Green and golden plover plentiful. Black-birds and thrushes singing throughout the month. Hedge banks in places bright with Herb Robert and Hare Bells. Wheat sowing much interfered with by rain and on some lands impossible. 6th. Christmas rose in blossom. 14th. Brimstone butterflies seen.

The Winter of 1888-9.

Taking the country and also the season as a whole, this was a rather cold, very dry and unusually gloomy winter. In the South of Ireland, in the West of Scotland and also in the North-east of England the weather remained as a rule mild, but in all other districts, after December, it was more or less unseasonably cold. In the Midland and Eastern counties there occurred two rather severe frosts, one at the end of the first week in January and the other about the middle of February. Fortunately, on each occasion these frosts

TABLE I.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1889.

No.	Name of Plant.	A. England, SW.				B. Ireland, S.		C. England, S.				D. England, Midlands.					Engl. E.	Engl. NW.	H. W.	I. NE.		
		Babacombe.	Tiverton.	Westward Ho.	Urk.	Wells.	Killarney.	Wicklow.	Pennington.	Buckhorn Weston.	Salisbury.	Basing.	Oxford.	Northamp- ton.	Thurleston.	Belton.	Mablethorpe.	Hodsock.	Thracolleston.	Settle.	Tynron.	Durham.
1	<i>Corylus Avellana</i>	54	19	..	53	..	37	45	38	71	32	17	..	65	..	..	78	27	..	38	..	..
2	<i>RANUNCULUS FICARIA</i>	52	42	29	39	51	..	25	31	18	14	87	73	75	32	51	118	48	25	86	93	81
3	<i>Mercurialis perennis</i>	54	31	83	48	52	..	..	92	17	52	86	..	82	86	..	..	51	83	86	16	..
4	<i>TUSSELAGO FABRICA</i>	74	70	49	55	71	78	57	60	48	53	..	76	77	88	74	120	72	77	89	..	45
5	<i>Narcissus Pseudo-narcissus</i>.....	..	68	..	..	..	..	..	70	..	..	..	..	..	..	82	113	84	88	..	..	..
6	<i>CALTHA PALUSTRIS</i>	82	100	92	76	78	73	82	89	48	71	..	..	91	96	102	95	112	91	101	122	117
7	<i>Salix caprea</i>	51	51	75	75	75	54	69	73	77	57	..	107	90	..	89	112	95	94	90	..	89
8	<i>ANEMONE NEMOROSA</i>.....	..	88	92	88	72	..	88	85	92	75	..	107	108	124	101	127	109	96	127	128	115
9	<i>Nepeta Glechoma</i>	97	96	52	95	91	48	90	107	77	86	..	107	108	124	101	127	109	96	127	128	115
10	<i>PRUNUS SPINOSA</i>	98	102	92	109	107	..	69	108	116	100	..	..	110	121	119	115	108	..	120	115	..
11	<i>PRIMULA VERIS</i>	91	..	..	113	..	105	106	109	76	91	..	..	110	106	111	120	108	..	119	..	117
12	<i>Cardamine pratensis</i>	119	101	92	83	107	114	106	95	105	101	..	122	112	122	116	127	117	114	..	..	122
13	<i>Stellaria Holota</i>	105	108	92	108	111	95	115	107	107	101	97	122	121	..	119	127	120	119	127	125	110
14	<i>SCILLA NOTANS</i>	114	108	108	115	90	105	..	114	103	100	..	..	110	112	102	124	128	122	121	..	122
15	<i>Ranunculus acris</i>	135	92	126	..	131	..	133	128	121	112	..	..	114	133	125	130	135	135	130	..	..
16	<i>Veronica Chamaedrys</i>	107	92	105	117	121	108	89	107	91	89	97	..	123	110	129	..	135	122	123	137	122
17	<i>Plantago lanceolata</i>	114	122	107	120	121	108	90	112	100	102	..	133	122	135	126	..	125	133	137	126	139
18	<i>Sisymbrium Alliaria</i>.....	..	108	101	115	112	112	99	107	101	110	..	122	111	127	117	135	120	113	..	..	..
19	<i>Vicia sepium</i>	128	122	..	..	115	76	90	135	116	122	..	160	137	147	137	149	178	138	142	135	..
20	<i>Ajuga reptans</i>	128	117	123	..	124	127	130	133	114	124	..	143	131	145	137	134	144	130	140	138	140
21	<i>GERANIUM ROBERTIANUM</i>	106	107	106	115	113	76	90	114	119	120	131	..	121	125	134	138	137	129	124	137	145
22	<i>Syringa vulgaris</i>	135	..	128	..	132	117	..	132	132	129	137	132	127	134	135	132	141	130	..	..	149
23	<i>Ericaceae Hippocastaneum</i>	130	..	130	..	134	123	124	129	133	127	131	132	128	130	134	128	140	123	..	..	..
24	<i>Gallium Aparine</i>	141	131	126	159	150	102	141	149	138	136	..	149	133	141	..	135	..	176	..	..	..
25	<i>Crataegus Oxycantha</i>	139	138	131	..	137	124	126	137	139	140	..	136	133	137	140	132	144	134	139	150	149
26	<i>Cytisus Laburnum</i>	136	..	..	..	137	124	134	134	141	134	..	135	134	146	141	138	143	138	141	..	..
27	<i>Potentilla anserina</i>	142	151	132	..	151	135	140	144	137	136	..	133	131	155	..	..	156	150	154	146	147
28	<i>Lotus corniculatus</i>	140	144	131	..	135	121	115	141	139	140	..	145	151	152	..	145	156	150	147	146	147
29	<i>Hieracium Pilosella</i>	140	..	148	155	146	140	144	146	141	141	..	..	160	..	..	157	..	150	158	152	..

TABLE I.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1889.—Continued.

No.	Name of Plant.	A. England SW.				B. Ireland, S.		C. England, S.				D. England, Midlands.				Engl. E.	Engl. NW.	H. Scottl.	W.	NE. Engl.			
		Babbacombe.	Tiverton.	Westward Ho.	Urk.	Wells.	Killarney.	Wicklow.	Fennington.	Buckhorn Weston.	Balsbury.	Swanley.	Baling.	Oxford.	Northamp- ton.	Thurcaston.	Belton.	Macclesfield.	Hodsock.	Tacolneston.	Settle.	Tyron.	Durham.
30	TRIFOLIUM REPENS	153	158	141	155	156	140	117	145	138	142	..	147	148	150	152	..	172	138	..	159	..	149
31	Chrysanthemum Leucanthemum ..	141	154	150	160	140	141	135	142	140	145	144	151	154	..	156	150	150	152	161	163
32	Lycchnis Flos-cuculi	151	152	157	166	..	156	156	155	139	138	144	152	152	152	168	..	162	162	159	165
33	Lathyrus pratensis	152	161	159	162	159	..	145	167	146	156	..	150	163	173	168	..	170	164	150	130	166	165
34	Iris Pseud-acorus	152	165	157	170	..	137	145	147	163	152	..	156	166	..	152	170	154	..	170	..	165	165
35	Rosa canina	163	161	154	166	154	162	160	157	155	159	156	..	163	164	154	..	170	150	162	159	165	
36	ACHILLEA MILEFOLIUM	168	164	167	175	183	..	172	170	182	166	..	175	164	185	..	170	170	..	165	181	175	
37	MALVA SYLVESTRIS	164	164	157	166	167	171	159	155	..	158	..	170	166	167	164	..	157	..	190	166	175	
38	Stachys agniotica	168	168	..	179	159	170	169	162	149	161	..	163	163	164	168	..	163	..	170	176	..	
39	Spirea Ulmaria	168	168	..	..	179	173	172	175	162	165	..	168	173	172	..	188	174	172	177	169	..
40	Prunella vulgaris	153	161	168	175	152	158	160	160	157	169	..	160	157	167	170	..	168	172	..	164	176	
41	Ligustrum vulgare	169	178	178	..	177	165	160	173	167	159	..	163	173	180	..	186	173	..	195	..	..
42	Vicia Cracca	186	186	171	170	175	176	172	167	159	169	..	..	164	173	178	..	172	..	174	162	166
43	Senecio Jacobaea	182	..	159	..	178	180	178	177	139	186	..	..	..	185	..	190	180	..	189	181	..
44	CENTAUREA NIGRA	193	164	176	177	173	186	172	178	180	187	..	173	163	173	178	184	180	172	176	196	..	
45	Galium verum	174	..	180	..	175	196	178	179	177	176	..	182	175	173	185	..	185	180	..	182	169	
46	Carduus arvensis	180	186	184	..	181	179	..	169	..	184	..	159	182	182	..	190	180	..	182	181	..	
47	CAMPANULA ROTUNDIFOLIA .....	..	..	..	..	201	188	..	167	..	193	..	..	199	..	..	177	188	..	176	176	178
48	Galopsis Tetralit .....	..	..	201	..	..	..	192	..	214	..	..	..	197	..	..	192	..	190	..	181	..
49	CONVOLVULUS SEPNUM	198	168	..	..	175	189	197	192	187	188	..	191	184	189	..	192	..	..	190	..	..
50	Hedera Helix	266	..	..	..	..	250	290	..	..	247	..	..	250	264	..	..	252	..	..	..	..

English Names of above Plants.—1. Hazel. 2. Lesser Celandine. 3. Dog's Mercury. 4. Gallsfoot. 5. Daffodil. 6. Marsh Marigold. 7. Great Sallow. 8. Wood Anemone. 9. Ground Ivy. 10. Black-thorn. 11. Cowslip. 12. Cuckoo Flower. 13. Greater Stitchwort. 14. Blue-bell. 15. Upright Crowfoot. 16. Germander Speedwell. 17. Ribwort Plantain. 18. Garlic Hedge Mustard. 19. Bush Vetch. 20. Bugle. 21. Herb Robert. 22. Lilac. 23. Horse Chestnut. 24. Cleavers. 25. Hawthorn. 26. Laburnum. 27. Silver-weed. 28. Bird's Foot Trefoil. 29. Mouse-ear Hawkweed. 30. Dutch Clover. 31. White Ox-eye Daisy. 32. Ragged Robin. 33. Meadow Vetchling. 34. Yellow Iris. 35. Dog Rose. 36. Milfoil. 37. Common Mallow. 38. Hedge Windwort. 39. Meadow-sweet. 40. Self-heal. 41. Prævel. 42. Tufted Vetch. 43. Ragwort. 44. Black Knap-weed. 45. Yellow Bedstraw. 46. Field Thistle. 47. Hare-bell. 48. Hemp-nettle. 49. Greater Bind-weed. 50. Ivy.

Until about the middle of May Wild Flowers were in most districts late in making their appearance, but after this time they came into blossom unusually early.

English Names of above Plants.—1. Hazel. 2. Lesser Celandine. 3. Dog's Mercury. 4. Coltsfoot. 5. Daffodil. 6. Marsh Marigold. 7. Great Sallow. 8. Wood Anemone. 9. Ground Ivy. 10. Black-thorn. 11. Cowslip. 12. Cuckoo Flower. 13. Greater Stitchwort. 14. Blue-bell. 15. Upright Crowfoot. 16. Germander Speedwell. 17. Ribwort Plantain. 18. Garlic Hedge Mustard. 19. Bush Vetch. 20. Bugle. 21. Herb Robert. 22. Lilac. 23. Horse Chestnut. 24. Cleavers. 25. Hawthorn. 26. Laburnum. 27. Silverweed. 28. Bird's Foot Trefoil. 29. Mouse-ear Hawkweed. 30. Dutch Clover. 31. White Ox-eye Daisy. 32. Ragged Robin. 33. Meadow Vetching. 34. Yellow Iris. 35. Dog Rose. 36. Milfoil. 37. Common Mallow. 38. Hedge Woundwort. 39. Meadow-sweet. 40. Self-heal. 41. Privet. 42. Tufted Vetch. 43. Ragwort. 44. Black Knap-weed. 45. Yellow Bedstraw. 46. Field Thistle. 47. Hare-bell. 48. Hemp-nettle. 49. Greater Bind-weed. 50. Ivy.

Until about the middle of May Wild Flowers were in most districts late in making their appearance, but after this time they came into blossom unusually early.

TABLE II.—DATE (DAY OF YEAR) OF FIRST SONG AND MIGRATION OF BIRDS, 1889.

District.	Stations.	SONG.						MIGRATION.							
		Song Thrush.	Nightingale.	Willow Wren.	Chiff-chaff.	Skylark.	Cuckoo.	Turtle Dove.	Flycatcher.	Swallow.	House Martin.	Sand Martin.	Swift.	Goatsucker.	Cornucake.
A.	Babbacombe .....	..	..	..	..	..	117	94	..	130	..	..	..	..	..
"	Usk .....	..	..	100	..	..	118	..	..	102	..	104	..	..	..
B.	Wicklow .....	..	..	..	118	..	120	..	..	98	..	..	128	..	120
C.	Pennington .....	..	117	..	119	..	103	..	..	107	..	132	129	139	138
"	Buckhorn Weston ..	..	110	..	115	..	108	..	125	108	100	..	131	138	140
"	Salisbury .....	..	..	..	..	..	111	..	..	120	..	..	..	..	..
"	Swanley .....	..	..	..	..	28	111	..	..	120	..	..	..	..	..
"	Ealing .....	..	112	85	..	..	114	..	..	108	..	..	125	..	..
D.	Oxford .....	..	..	..	..	..	113	..	..	114	..	..	124	128	128
"	Northampton .....	..	..	..	..	..	112	..	..	109	..	..	..	..	..
"	Belton .....	..	115	117	98	..	116	..	..	112	123	122	132	..	125
"	Macclesfield	48	..	..	..	62	..	..	..	..	124	126	135	..	128
"	Hodsock .....	..	120	..	112	..	119	127	127	98	124	124	128	..	123
E.	Tacolneston .....	..	119	..	..	..	116	128	..	118	..	..	..	..	..
F.	Settle .....	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H.	Tynron .....	..	..	..	..	..	118	..	..	121	130	..	..	..	128
I.	Durham	38	..	122	..	45	121	..	112	112	129	134	132	..	130

TABLE III.—DATE (DAY OF YEAR) OF FIRST APPEARANCE OF INSECTS AND FROG SPAWN, 1889.

District.	Station.	1. <i>Melolontha vulgaris</i> .	2. <i>Apis mellifica</i> .	3. <i>Vespa vulgaris</i> .	4. <i>Pieris brassicae</i> .	5. <i>Pieris rapae</i> .	6. <i>Anthracis cardamines</i> .	Frog Spawn.	Tadpoles.
		1.	2.	3.	4.	5.	6.		
A.	Usk .....	..	..	..	..	108	..	..	154
B.	Killarney	136	..	..	..	107	140	..	..
"	Wicklow .....	..	..	138	105	136	116	..	..
C.	Pennington	134	144	116	134	107	133	..	145
"	Buckhorn Weston ..	132	..	121	105	106	136	..	..
"	Salisbury .....	..	..	..	124	97	140	57	110
"	Swanley .....	..	..	..	..	125	141	..	..
"	Ealing .....	..	..	..	..	126	..	97	..
D.	Oxford .....	..	..	..	135	92	136	93	..
"	Northampton .....	..	..	..	128	..	..	..	..
"	Belton .....	..	..	..	127	119	157	79	..
"	Macclesfield .....	..	124	82	139	124	..	..	..
"	Hodsock .....	..	163	114	145	126	138	..	..
E.	Tacolneston .....	..	..	..	..	..	129	91	..
I.	Durham .....	..	..	108	153	138	140	84	..

English Names of above Insects.—1. Cock Chafer. 2. Honey Bee. 3. Wasp. 4. Large Cabbage Butterfly. 5. Small Cabbage Butterfly. 6. Orange-tip Butterfly.

lasted only a few nights, and the weather being dry at the time, but little injury was done by them. Indeed, as regards both farm and garden crops, they served to give a wholesome check to their growth, which, owing to the great mildness of November and December, was becoming dangerously forward. In many parts of the country, however, no frosts worth mentioning

TABLE IV.—ESTIMATED YIELD OF FARM CROPS IN 1889.

Description of Crop.	England.					
	A. SW.	C. S.	D. Mid.	E. E.	F. NW.	I. NE.
Wheat	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Barley	O. Av.	O. Av.	U. Av.	O. Av.	Av.	O. Av.
Oats	O. Av.	O. Av.	U. Av.	O. Av.	Av.	U. Av.
Corn Harvest began,	222	215	227	218	224	226
average Date,	(Aug. 10)	(Aug. 3)	(Aug. 15)	(Aug. 6)	(Aug. 12)	(Aug. 14)
Beans	U. Av.	Av.	U. Av.	U. Av.	..	Av.
Peas	Av.	Av.	U. Av.	Av.	..	Av.
Potatoes	O. Av.	O. Av.	O. Av.	Av.	O. Av.	Av.
Turnips	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	Av.
Mangolds	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Hay	Much	Much	Much	Much	Much	Much
	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.

Description of Crop.	Scotland.			Ireland.	British Isles.
	H. W.	J. E.	K. N.	B. and G. S & N.	
Wheat	O. Av.	O. Av.	..	O. Av.	O. Av.
Barley .....	..	Av.	..	O. Av.	O. Av.
Oats	O. Av.	U. Av.	U. Av.	Av.	Av.
Corn Harvest began,	234	238	339	228	227
average Date,	(Aug. 22)	(Aug. 26)	(Aug. 27)	(Aug. 16)	(Aug. 15)
Beans .....	..	..	..	..	U. Av.
Peas .....	..	..	..	..	U. Av.
Potatoes	O. Av.	O. Av.	Av.	Av.	O. Av.
Turnips	O. Av.	Av.	Av.	Av.	O. Av.
Mangolds .....	..	..	..	O. Av.	O. Av.
Hay	O. Av.	O. Av.	U. Av.	Much	Much
	O. Av.	O. Av.	U. Av.	O. Av.	O. Av.

O. Over. U. Under. Av. Average.

This Table has been compiled from Returns sent in to the *Agricultural Gazette* at the end of the Summer.

occurred until the middle of the last month of the quarter. In these districts there was throughout the whole winter a fair sprinkling of wild and garden flowers to be seen.

Observers' Notes.

DECEMBER.—*Babbacombe* (A.). Owing to the unusual mildness of the season, birds were singing, trees budding and many flowers in blossom throughout the month. *Pennington* (C.). Primroses out in woods and lanes, throughout the month, and in the gardens periwinkle and polyanthus also in blossom. 5th. Chaffinch singing. 6th. Brimstone Butterfly seen. 28th. A blackberry blossom gathered. *Macclesfield* (D.). The gardens looked fresh at Christmas and the grass greener than I remember it to have been at that time of year.

JANUARY, 1889.—*Babbacombe* (A.). Owing to the absence of severe frost, many flowers, including roses, were in bloom, while birds were singing throughout the month. *Wicklow* (B.). A very mild month. Crocuses out in the borders during the last week, also quantities of primroses and wallflowers. The Abutilon in flower all the winter. Thrushes have had their full song all this month, like as in spring. *Pennington* (C.). Wild flowers unusually plentiful and birds singing. Plover scarce. 1st. Primroses, polyanthuses, periwinkles, wallflowers and garden anemones in bloom. 15th. Daphne laurels in blossom. 20th. Barren strawberry in flower—earliest date since 1884, when it was out on the 9th.

TABLE V.—ESTIMATED YIELD OF FRUIT CROPS IN 1889.

Description of Crop.	England.					
	A. SW.	C. S.	D. Mid.	E. E.	F. NW.	I. NE.
Apples	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.
Pears	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.
Plums	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	..
Raspberries	O. Av.	O. Av.	O. Av.	O. Av.	Av.	O. Av.
Currants	O. Av.	O. Av.	O. Av.	O. Av.	Av.	Av.
Gooseberries	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Strawberries	Much	Much	Much	Much	Much	Much
	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.

Description of Crop.	Scotland.			Ireland.	British Isles.
	H. W.	J. E.	K. N.	B. and G. S & N.	
Apples		U. Av.		U. Av.	U. Av.
Pears		U. Av.		U. Av.	U. Av.
Plums		O. Av.		Av.	U. Av.
Raspberries		O. Av.		O. Av.	O. Av.
Currants		O. Av.		O. Av.	O. Av.
Gooseberries		O. Av.		O. Av.	O. Av.
Strawberries		Much		Much	Much
		O. Av.		O. Av.	O. Av.

O. Over. U. Under. Av. Average.

This Table has been compiled from Returns sent in to the *Gardeners' Chronicle* and the *Garden* during the Autumn.

23rd. Snowdrop in blossom. 31st. Celandine in bloom—earliest date for six years. *Buckhorn Weston* (C.). A great quantity of primroses in blossom, not only in sheltered nooks but in more exposed places. Thrushes have been singing all the month, and I have found two blackbirds' nests in process of building. Rooks, too, have begun to build. *Salisbury* (C.). Up to the end of the month, no frog spawn had been seen. 21st. No fertile flowers of the Hazel could be found. Catkins unusually small. Vegetation generally was, at this time, by no means remarkably forward. *Hodsock* (D.). At the end of the month a few snowdrops and aconites were in flower, also a few primroses. 27th. Both barren and fertile flowers of the Hazel in blossom.

FEBRUARY.—*Usk* (A.). Have noticed comparatively few fieldfares this year. *Pennington* (C.). Vegetation made scarcely any progress during this month. 9th. A pear in blossom—a solitary flower. 25th. Yew in blossom. *Macclesfield* (D.). 2nd. A change to colder weather. Many plants were killed—wallflowers, pansies, &c. 8th. Heavy snow storm, the branches of many trees and shrubs broken by the weight of snow. Plum trees and Scotch firs suffered most. *Hodsock* (D.). Snowdrops in full flower. *Tacolneston* (E.). 2nd. Pyrus Japonica, with a good many flowers open, on a sheltered south wall. These blossoms were, however, destroyed by frost during the second week.

The Spring of 1889.

This was in all districts a more or less cold spring, with a heavy rainfall and a considerable amount of bright sunshine. Early in March there occurred in most localities an unusually severe frost. Indeed, the weather was then in many places colder than at any time during the three previous winter months. The only districts which appear to have escaped this frost

were Ireland South and England South-west and West. During April no damaging cold was recorded, but throughout a great part of the month low temperatures prevailed almost everywhere. The absence of night frosts in May was the most marked characteristic of that month, and as affecting vegetable growth the most noteworthy feature of the year. Until the end of April vegetation was almost everywhere very backward, but the warm showery weather which May brought with it wrought a complete change, and from this time a very rapid advance was made. The foliage of trees at the close of the season was remarkably luxuriant. Several observers, both in the warmer as well as the colder districts, mention the absence of bloom on the beech and ash. On the other hand, the blossom on such fruit trees as apples, pears, cherries, &c., proved unusually abundant. Nevertheless, on close examination these blossoms were found to be in many cases imperfectly formed, while the young leaves suffered greatly from the ravages of caterpillars and aphids. As regards birds, the spring migrants seem everywhere to have been less numerous than usual, and to have been, moreover, late in making their appearance.

Observers' Notes.

MARCH.—*Babbacombe* (A.). 27th. Hawthorn in leaf. *Usk* (A.). Vegetation generally stationary after about the 20th, owing to cold weather. *Wells* (A.). Vegetation backward, not so much from prolonged or severe cold as from absence of sunshine and cold dampness. *Pennington* (C.). Spring sowing on heavy soil very backward by end of month, owing to frequent rains. 16th. *Darwinii Berberis* in flower. 26th. Missel Thrush's nest, with two eggs in it. 29th. Saw one Peacock, three Brimstone and two small Tortoiseshell butterflies. *Salisbury* (C.). 22nd. Peach in blossom. 31st. The first water spider seen. *Ealing* (C.). The garden spring flowers are backward. Crocuses were not abundant till the 13th. *Northampton* (D.). There having been but very little sunshine and not many warm days, vegetation was very backward at the end of the month. *Hodsock* (D.). 19th. Eggs in Thrush's nest. 29th. A few green leaves on Hawthorn in sheltered places.

The Summer of 1889.

The summer of the past year was, on the whole, a cold, wet and sunless one. Throughout June the weather continued changeable, but for the most part warm and summer like. The record of sunshine was, moreover, large, while very little rain fell after the first week. On the other hand, during nearly the whole of July and August the temperature ruled persistently low, and there was comparatively little bright sunshine. The total rainfall in these two months was not much in excess of the average; but then, again, there occurred very few fine days. During June and the first half of July vegetation generally was very forward, and the hedgerows, fields and woods were even gayer than is usual at this season with wild flowers. The crop of hay proved an abundant one, and nearly the whole of it was harvested early and in splendid condition. The drought which prevailed in most districts during the latter half of June and the early part of July was at the end of this period becoming much felt, so that the moister and cooler weather which followed was at first greatly welcomed. Unfortunately, however, for the cereals, and more particularly for the wheat crop, these cooler conditions

lasted, almost without a break, until the close of the summer, while storms of rain were here and there at times exceptionally heavy. Where the rainfall was lightest many deciduous trees were, in the latter part of August, already beginning to lose some of their foliage. The corn harvest, notwithstanding many interruptions from rain, was in some of the earliest districts completed before the close of the summer; in fact, in most other places a great deal of corn had been carried before the month of August came to an end. This was a splendid summer for roots and all kinds of vegetables.

Observers' Notes.

JUNE.—*Babbacombe (A.)*. Haymaking began on the 13th. The crop was heavy, and the dry weather in the latter half of the month was most favourable for its ingathering. Vegetation was very forward. *Westward Ho (A.)*. 9th. This was the only really wet day. *Pennington (C.)*. Roses were at their best before the end of the month. Flowers on elder abundant. No turnip fly. The Nightingale finished its song at the beginning and the cuckoo by the middle of the month. Wheat promising well at end of month. 10th. Pasture grass cut; carried by the 28th; 40 acres in all. 11th. Gathered first strawberry. 26th. Gathered first raspberry. *Buckhorn Weston (C.)*. Hay crop very early and abundant, and harvested in good condition. Great quantity of blight of every sort, and foliage much injured. Very few swallows indeed; also very few martins. *Oxford (D.)*. Hay excellent in quantity and quality. It is many years since there was so good a crop. Wild flowers very plentiful. 2nd. Acacias (*Robinias*) in full leaf. 12th. Cuckoo last heard. *Northampton (D.)*. Hay crop got in very successfully. *Macclesfield (D.)*. Vegetation up to the last week never looked better in Cheshire. Grass crops unusually heavy. First grass cut on 12th. By the end of the month fully one-half the hay had been secured, mostly without rain. Apples falling numerous at the end of the month through drought. *Tynron (H.)*. Vegetation very forward. Scarcely any rain during the last three weeks.

JULY.—*Babbacombe (A.)*. The abundant rain from the 7th to 25th did great good to the pastures, which had become parched through the long drought. *Pennington (C.)*. Harvest operations commenced on the 13th. *Buckhorn Weston (C.)*. July has been throughout wet and cold. *Macclesfield (D.)*. Leaves of the lime beginning to fall on the 29th, owing to the recent drought. Meadows and pastures very brown until towards the middle of the month.

AUGUST.—*Babbacombe (A.)*. Wheat was cut on the 6th and harvest finished by the 31st. The yield was good. *Pennington (C.)*. The ingathering of the harvest, which commenced early, was much retarded by the rainy weather. 24th. Finished carrying wheat. 29th. Harvest finished. *Hodsock (D.)*. Corn all cut by the end of the month, and about half of it carried. A good many leaves falling, especially from the beeches, at the end of the month.

The Year ending August 1889.

Taking the country generally, the most noteworthy features of the weather of the past phenological year, as affecting vegetable life, may be briefly summed up as follows:—1. The unseasonably sharp frosts and continued cold in October, which gave a sudden and premature check to vegetation generally. 2. The moist warmth of November, which started all things growing again. 3. The absence during the winter of any cold period of sufficient duration to arrest this renewed growth. 4. Some severe frosts in March, which at last brought everything more or less to a standstill. 5. A frostless May and brilliant June, which enabled all the new growths to be made without the slightest check or injury. 6. A persistently cold, wet and gloomy July and August, which at first did much good by bringing to an end a drought which at one time threatened to become serious, but which afterwards served to

undo much that the bright and genial weather of the two previous months had succeeded in accomplishing.

Taken as a whole, this proved an unusually gay and bountiful year.

DISCUSSION.

The PRESIDENT (Dr. Marcet) said that these reports were always interesting, and as the Rev. T. A. Preston had given up the work of discussing these Phenological observations, Mr. Mawley had undertaken to go on with it, so that these reports could still be looked for.

Mr. SOUTHALL expressed his satisfaction with Mr. Mawley's report, as it pointed out in a clear manner what he had himself been able to observe concerning the progression of the seasons. Mr. Mawley had mentioned that there were no frosts in May during the past season, but in his own locality (Ross) no frosts were experienced from March 26th until the middle of October.

Mr. MAWLEY said that it was, of course, impossible to compare the observations given in the table of Flowering Plants in the same way that observations taken with meteorological instruments could be compared, but that nevertheless many interesting particulars respecting the character and progress of the seasons and their influence on vegetation might be obtained from this table and the observers' notes.

SUNSHINE.

By ALEX. B. MACDOWALL.

[Read November 19th, 1889.]

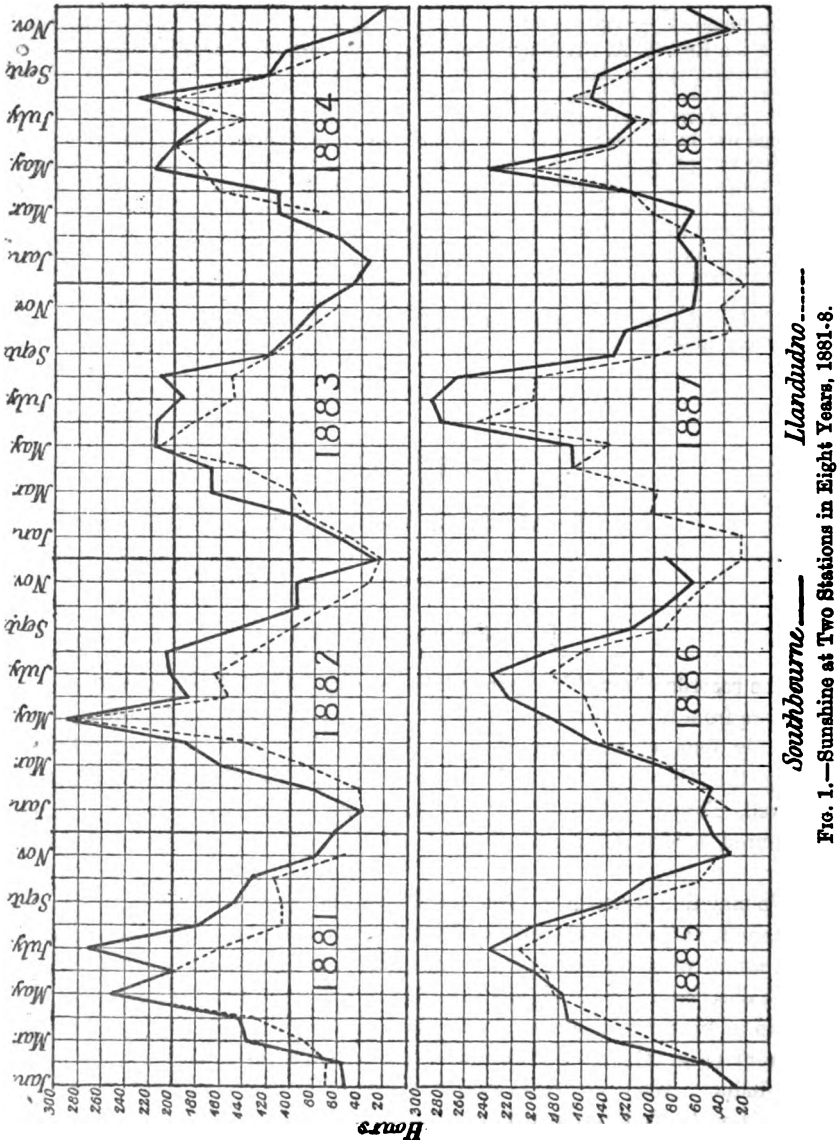
As the records of sunshine accumulate, new points of view of the phenomenon are from time to time obtainable. In the *Meteorological Record* we have monthly data of sunshine from 24 stations (end of 1888), most of them using the Campbell-Stokes instrument, but a few (Buxton, Wallington, Stowell, Torquay) that of Jordan, which is understood to record, when measured before development, about 11 per cent. more sunshine than the other.

We may find it useful to make out a curve of the sunshine at one of those stations for a series of years, and for this purpose I select Southbourne-on-Sea, a new watering place near Christchurch, in Hants (where Dr. Compton is the observer). It stands high in the list of comparative sunshine, and furnishes a nearly continuous curve from the beginning of 1881, as in the diagram (Fig. 1). A dotted line curve is added for a northern station—Llandudno. While corresponding with the other to some extent, less sunshine is evidently the rule at this station.

The sunniest year of this Southbourne record is 1887 (Jubilee year), when 1,822 hours were recorded; the least sunny, 1888, with 1,828. The curve, it will be seen, varies considerably from year to year. How unlike are the curves for the two years just referred to!

Taking the averages of the monthly figures in the nine years, 1880-88, we have the following series for seven months of the year :—

April.	May.	June.	July.	Aug.	Sept.	Oct.
15	218	197	214	198	188	104



Southbourne ——— Ilandudra -----
FIG. 1.—Sunshine at Two Stations in Eight Years, 1881-8.

This gives two maxima, viz. in May and July, that in July being but slightly under that in May. Regarding this series for a moment as approximately the type (and the time considered is of course rather short), we may note

how not one of the annual curves here given corresponds closely with the typical one. In some years there is but one maximum; and while in most there are two, these occur, in four of the years, in May and August respectively. In 1881 they fall in May and July, but that in July is the greater.

The occurrence of two maxima seems to be usual; and while there is only a suggestion of the earlier maximum in the Southbourne curve for 1887, we find this maximum quite evident in the curves for some other places, shown in Fig. 2. These four stations (Blackpool, Buxton, Eastbourne, and St.

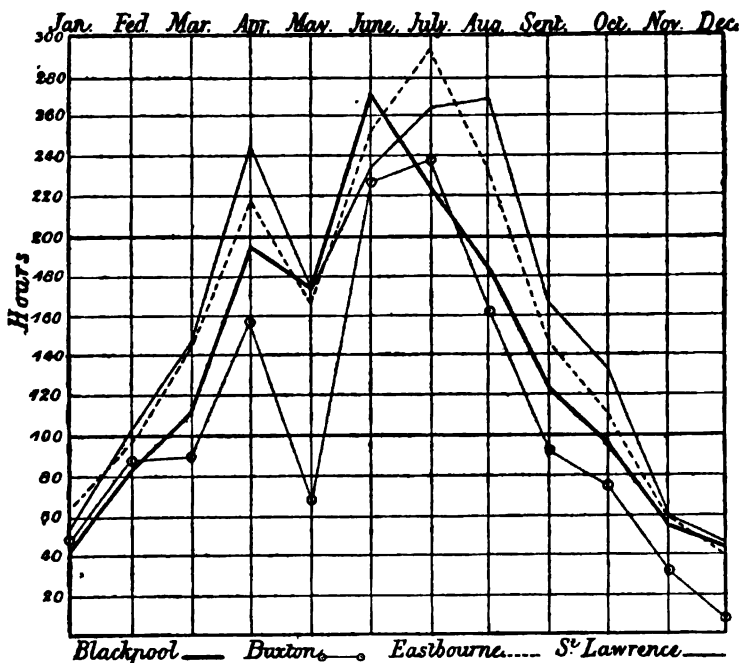


FIG. 2.—Sunshine at Four Stations, 1887.

Lawrence, Ventnor), are pretty far apart from each other, and they all show an early maximum in April; but the second, and in this year higher, maximum, appears for Blackpool in June, for Eastbourne and Buxton in July, and for St. Lawrence in August. This diagram shows further the general inferiority of Buxton, in the amount of sunshine this year, to the other three stations; and while Eastbourne attained the highest monthly amount, the values for St. Lawrence are generally higher than those for Eastbourne.

The following is a list of the 20 stations, yielding records in 1887, in the order of amount of sunshine for that sunny year, along with a similar list of same stations for the sunless year 1888 :—

1887.	Hours.	1888.	Hours.
1. Bousdon	1933	1. Eastbourne	1461
2. St. Lawrence	1902	2. St. Lawrence	1441
3. Eastbourne	1829	3. Bousdon	1412
4. Southbourne	1822	4. Southbourne	1328

1887.	Hours.	1888.	Hours.
5. Cullompton	1784	5. Hillington	1309
6. Harestock	1761	6. Harestock	1282
7. Church Stoke	1698	7. Newton Reigny	1246
8. Hillington	1677	8. Church Stoke	1216
9. Blackpool	1596	9. Llandudno	1210
10. Kew	1592	10. Cullompton	1206
11. Berkhamsted	1569	11. Aspley Guise	1191
12. Aspley Guise	1566	12. Blackpool	1173
13. Newton Reigny	1476	13. Kew	1157
14. Hodsock	1420	14. Greenwich	1068
15. Greenwich	1401	15. Hodsock	1065
16. Llandudno	1376	16. Berkhamsted	1045
17. Southwell	1337	17. Southwell	1040
18. Buxton	1267	18. Bunhill Row	911
19. Bolton	1182	19. Buxton	819
20. Bunhill Row, London	1083	20. Bolton	787

The order is evidently very much the same. The greatest difference is Llandudno—16th in one list, 9th in the other ; then come Newton Reigny 18th and 7th, Cullompton 5th and 10th, &c. The values of the first list are in general reduced in the second by about a fourth.

In a paper on "Measurement of Sunshine," read to the Society on March 18th, 1885, Mr. Scott discussed the records of sunshine for five years or less at a large number of stations, including some in Scotland and Ireland. He noted, *inter alia*, an absolute maximum in May, and a second maximum for the South of England in August.

Longer series of observations being now available, the present paper chiefly aims at showing further how the phenomenon in question has varied recently from year to year at a selected station, and how it has varied in a selected year at some different places.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

NOVEMBER 20TH, 1889.

Ordinary Meeting.

WILLIAM MARCET, M.D., F.R.S., President, in the Chair.

WILLIAM WATERS BUTLER, Crown Brewery, Birmingham ;
JOHN EDWARD CULLUM, Valentia Observatory, Co. Kerry ;
JOHN DOVER, B.A., Elmfield, Totland Bay, Isle of Wight ;
RICHARD GORTON, Claremont Place, Cirencester ;
RALPH HEAP, M.A., Brick Court, Temple, E.C. ;
VINCENT ALEXANDER LAWSON, C.E., 9 Rowcroft, Stroud ;
EDWARD MUSGROVE, Junr., The Hollies, Sidcup ;
JOHN ROSE-INNES, B.A., B.Sc., 148 Kensington Park Road, W ; and
JOHN CLOUGH THRESH, D.Sc., M.B., The Limes, Chelmsford,
were balloted for and duly elected Fellows of the Society.

The following Papers were read :—

"SECOND REPORT OF THE THUNDERSTORM COMMITTEE.—DISTRIBUTION OF THUNDERSTORMS OVER ENGLAND AND WALES, 1871-1887." By WILLIAM MARRIOTT, F.R.Met.Soc. (p. 1.)

"ON THE CHANGE OF MEAN DAILY TEMPERATURE WHICH ACCOMPANIES THUNDERSTORMS IN SOUTHERN ENGLAND." By G. M. WHIPPLE, B.Sc., F.R.Met.Soc. (p. 12.)

"NOTE ON THE APPEARANCE OF ST. ELMO'S FIRE AT WALTON-ON-THE NAZE, SEPTEMBER 3RD, 1889." By W. H. DINES, B.A., F.R.Met.Soc. (p. 15.)

"NOTES ON CIRRUS FORMATION." By H. HELM CLAYTON. (p. 16.)

"A COMPARISON BETWEEN THE JORDAN AND THE CAMPBELL-STOKES SUNSHINE RECORDER." By F. C. BAYARD, LL.M., F.R.Met.Soc. (p. 20.)

"SUNSHINE." By A. B. MACDOWALL. (p. 61.)

"ON CLIMATOLOGICAL OBSERVATIONS AT BALLYBOLEY, CO. ANTRIM." By Prof. S. A. HILL, B.Sc., F.R.Met.Soc. (p. 24.)

DECEMBER 18TH, 1889.

Ordinary Meeting.

WILLIAM MARCET, M.D., F.R.S., President, in the Chair.

GUSTAV VALENTIN ALSING, C.E., St. Paul's Chambers, Sheffield;
 Col. WILLIAM FRANCIS BADGLEY, Kyrewood House, near Tenbury;
 GEO. RUSSELL BEARDMORE, L.R.C.P., Warwick House, Upper St., Islington, N.;
 GEORGE DAVID BELLAMY, C.E., 8 Gordon Terrace, Plymouth;
 HENRY FRANKLIN BELLAMY, C.E., Selangor, Malay Peninsula;
 Capt. WILLIAM A. BENTLEY, R.A., Hurdlestown, Broadford, Co. Clare;
 W. LONGLEY BOURKE, C.E., Westbrook, Eccles, Manchester;
 JAMES COLLIE, C.E., Burgh Hall, Dunoon;
 JOHN BREEDON EVERARD, C.E., 6 Millstone Lane, Leicester;
 THOMAS FENWICK, C.E., Chapel Allerton, near Leeds;
 HENRY GALE, C.E., F.R.G.S., 45 Elvaston Place, Queen's Gate, S.W.;
 SAMUEL GRIFFIN, C.E., Kingston Iron Works, Bath;
 Prof. MARK W. HARRINGTON, M.A., Ann Arbor, Michigan, U.S.A.;
 WILLIAM WILSON HULSE, C.E., Withington, Manchester;
 JAMES EDWARD LINGARD, C.E., 5 Normanton Road, Derby;
 L. LIVINGSTONE MACASSEY, C.E., Stanleigh, Holywood, Belfast;
 Surgeon-Major JOHN ALEXANDER MCCracken, St. Ann's Garrison, Barbados;
 FRANK MASSIE, C.E., Tetley House, Kirkgate, Wakefield;
 FRANK MEAD, C.E., Sutton, Surrey;
 RICHARD R. MENNEER, C.E., Indian Public Works, Sind, India;
 JOSEPH MITCHELL, C.E., Bolton Hall, Bolton-on-Deane, near Rotherham;
 FRANK MORRIS, C.E., Brentford Lodge, Old Brentford;
 BONNER HARRIS MUMBY, M.D., Iver Lodge, Merton Road, Southsea;
 WILLIAM BESWICK MYERS, C.E., F.G.S., 75 Avenue Road, N.W.;
 WILLIAM J. NEWTON, C.E., Town Hall, Acorington;
 JOHN PARKER, C.E., Nelson Villa, Hereford;
 Sir ROBERT RAWLINSON, K.C.B., C.E., 11 The Boltons, West Brompton, S.W.;
 ISAAC SHONE, C.E., 50 Nevern Square, S.W.;
 Capt. JOHN SHORTT, R.N., Hobart, Tasmania;
 HENRY SIMON, C.E., 20 Mount Street, Manchester;
 JOHN GODFREE SINGLE, C.E., 7 Morley Street, Plymouth;
 Maj.-Gen. FREDERICK SMITH STANTON, R.E., The Grove, Hillingdon, Uxbridge;
 THOMAS WILLIAM STONE, C.E., 189 Goldhawk Road, W.;
 JOHN HARRIS HAZLETT SWINEY, B.A., C.E., 6 Chichester Avenue, Belfast;
 ROBERT LETHBRIDGE TAPSCOTT, C.E., 41 Parkfield Road, Liverpool;
 GEORGE WALLER WILLCOCKS, C.E., 9 Hume Street, Dublin;
 JOHN AVERY BRANTON WILLIAMS, C.E., Queen's Chambers, Cardiff;
 EDWARD WOODS, C.E., 45 Onslow Gardens, S.W.; and
 Capt. NICOLAS ZELENOI, Beaufort Mansions, Queen Anne's Gate, S.W.,
 were balloted for and duly elected Fellows of the Society.

Mr. J. S. HARDING and Mr. H. S. WALLIS were appointed Auditors of the Society's Accounts.

The following Papers were read :—

"REPORT OF THE WIND FORCE COMMITTEE ON THE FACTOR OF THE KEW PATTERN ROBINSON ANEMOMETER." Drawn up by W. H. DINES, B.A., F.R.Met.Soc. (p. 26.)

"ON TESTING ANEMOMETERS." By W. H. DINES, B.A., F.R.Met.Soc. (p. 41.)

"ON THE RAINFALL OF THE RIVIERA." By G. J. SYMONS, F.R.S., F.R.Met.Soc. (p. 44.)

"REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1889." By EDWARD MAWLEY, F.R.Met.Soc. (p. 52.)

CORRESPONDENCE AND NOTES.

"SQUALL AT DOVER, AUGUST 5th, 1846." BY ROBERT LAWSON, LL.D., F.R.Met.Soc., Inspector-General of Hospitals.

THE following description of an extensive squall, which I witnessed at Dover forty-three years ago, may even yet prove interesting to the Fellows of the Royal Meteorological Society. This occurred on August 5th, 1846, and the account of the appearances, which is given below verbatim, was drawn up on the 8th, while the details were fresh in the memory.

While going over the heights between the Barracks and Hospital, on the morning of the 5th, about a quarter before 9 a.m., I was struck with the rate at which a ship about $1\frac{1}{2}$ mile off shore going south was running; she was under topsails, topgallants, courses, and jib; in a few minutes (not above 2 or 3) the breeze increased so much that she was obliged to let fly her topgallant sheets, let go her topsail halyards, and, notwithstanding, bear up immediately. At this time there was a long line of cloud, extending from the South Foreland off about South-south-west by compass, for 6 or 8 miles; this was in rapid motion, whirling and turning on itself, and was about perpendicular to the ship mentioned. There was a ripple on the water from the vessel towards the shore about a mile at the time she bore up; inside this ripple the water was then smooth, and on the height where I then was there was no wind. At this time I noticed a slight whirlwind, just on the line between the smooth and rough water, which carried up a spray for about 50 feet and then ceased; the spray distinctly whirled against the sun, there was no cloud formed at its top, it lasted not a quarter of a minute. Seven or eight minutes afterwards the cloud previously mentioned had increased considerably, and masses of vapour from it were flying above right towards the land, while below the breeze quickly extended to the shore blowing off the land, and freshened rapidly. In less than ten minutes afterwards a slight shower fell, after which the clouds all cleared away, and a brisk breeze came on from the northward.

The previous night there had been a violent thunderstorm; early in the morning the wind was about North-east by compass, slight, weather overcast, close, and rather hazy. At a quarter to 9 there was a pretty general stratum of cirro-stratus moving very slowly from about South-west, between which and the cloud mentioned above was an extensive interval; the weather then, too, was pretty clear. There was no lightning seen nor thunder heard during the above. The squall extended for a long way under the cloud, as was obvious from vessels shortening sail and bearing up, though it nowhere seemed so violent as right off the height I was on. The wind at the Castle (a mile off), as was evident from the fly of the Jack there, was off the land, while the clouds over it were flying inland. The whole phenomenon scarcely occupied 20 minutes. I did not detect the direction of the wind in the offing beyond the cloud.

HEAVY RAINFALL IN CLARE AND GALWAY, IRELAND, ON SEPTEMBER 1ST, 1887.
 By CAPT. W. A. BENTLEY, R.A., F.R.Met.Soc.

I HAVE made exhaustive inquiries as to the rainfall of September 1st, 1887, in the counties of Clare and Galway. I wrote to nearly every person who I thought could give any information on the subject, and the replies I received were all more or less of an interesting nature.

The rain-gauges in Clare are situated on a line which runs nearly east and west through the country—from Killaloe on the east to Miltown Malbay on the west. There are no gauges north of this line in Clare.

The county Galway gauges are nearly all on a line, which also runs nearly east and west. The railway from Ballinasloe to the City of Galway marks approximately the position of this line. There are no gauges in Galway south of it, but north of it there are five, viz. three in the neighbourhood of Tuam and two at Kylemore Castle, which is about two miles east of Letterfrack.

The great rainfall of September 1st, 1887, was a very remarkable one, for both the morning and the evening of that day were fine at nearly every station that has sent me a report. The principal fall took place on a line drawn from Loop Head to the City of Galway. The observer at Miltown Malbay reports: "The morning opened very fine, so that I was induced to put my men at hay-making. The sky was quite clear, and not a cloud was to be seen. At 10 a.m. two clouds commenced to form well above the horizon, not larger at this time than good-sized haystacks. One was to the south-west over Loop Head, and the other was a few points north of it. Such wind as there was at the time was from the North-west. The two clouds rapidly increased in density and volume. The wind suddenly backed to the South-west, but the force was not much increased. The rain began at 11 a.m. and ended at 3 p.m. Between those hours there were two breaks in the rain; in fact, the rain on that day consisted of three great showers. I estimated the breadth of the dark cloud as from four to five miles. The rain came down in torrents. In a short time every hollow in the ground was converted into a lake, and all the low flat lands were under water. I lay at full length on the ground longside a five-foot stone wall for shelter. Not a drop of rain touched me; but I was wet to the skin in less than ten minutes with the spray from the top of the wall and from the ground longside me. The heavy part of the rainfall from the centre of the dark cloud did not cover a frontage of more than $1\frac{1}{2}$ miles."

The cloud passed over Burren in the direction of Galway City. In the neighbourhood of Lisdoonvarna a bridge was carried away by a flood that afternoon, and a horse wandering on the public road near Lemenagh Castle was drowned. The gauge at Miltown Malbay recorded a fall of 2·05 inches.

At the Court House at Ennis it rained for 12 hours on that day, but the fall was not a heavy one, being only ·60 in. The first five days of September 1887 were very wet at Ennis; 3·30 ins. of rain fell during that time.

At Kilkishen Glebe there was a much larger rainfall than at Ennis, ·97 in. being the record there.

My gauge at Hurdlestown recorded a fall of ·56 in. on that day. I regret I cannot give any information as to the duration of the rain, or to the direction of the wind.

Now as to the observations made in the County of Galway.

The rainfall at Ballinasloe was 1·23 in. The rain began at 12·30 p.m., and it is not recorded at what time it ended. The wind was from the West, and was of moderate force.

The fall at Garbally Gardens, near Ballinasloe, was 1·03 in. The barometer fell very rapidly. On August 31st it was 29·20 ins., and on September 1st it was 28·75 ins. The temperature on that day was:—Highest 59°, lowest 50°. I find that the observer at Garbally does not follow the well-known meteorological rule which directs all observations to be made at 9 a.m. He states that he measured the rain at 6·30 p.m. on September 1st, and at 6·30 p.m. on the 2nd again, and found the gauge contained ·93 in. It is certain that part of this ·93 should be added to the observation made on the 1st at 6·30 p.m. He also states that the rain began on the 1st at 4·30 p.m., and that the amount recorded (1·03) fell in about an hour. I would put much more faith in the report of the observer at Ballinasloe, who is a civil engineer by profession. Garbally is quite close to Ballinasloe.

RAINFALL, SEPTEMBER 1st, 1887.

	Station.	Observer.	Rain Gauge.			Amount.
			Height above Ground.	Height above Sea Level.	Diameter.	
Co. Clare Rain Gauges.	Miltown Malbay	M. Molohan	Ft. Ins.	Ft.	Ins.	Ins.
	Ennis (Court House)	John Hill, C.E., F.R.Met.Soc.	1 0	400	5	2'05
	Kilkishen Glebe	Canon Lloyd, M.A.	3 2	21	10 (sq.)	0'60
	Hurdlestown Broadford	Capt. Bentley, F.R.Met.Soc.	4 4	113	5	0'97
Co. Galway Rain Gauges.			1 0	164	5	0'56
	Ballinasloe	W. H. Kempster, C.E.	0 6	150	5	1'23
	Garbally, Ballinasloe	J. Cobban	1 0	157	8	1'03
	Woodlawn	A. Porter	3 6	300	5	0'17
	Galway (Queen's Col.)	Prof. Anderson	1 0	22	5	4'93
	Gardenfield	H. Kerwan	1 0	155	5	2'75
	Tuam	....	6 0	160	5	2'75
	Kylemore House	T. McNab	1 0	105	5	0'85
	Kylemore Castle	Mr. MacKinnon	..	..	..	1'55

At Woodlawn, which is about ten miles west of Ballinasloe, the rainfall was only .17 in. This is very strange, as Woodlawn is situated between Ballinasloe and Galway City, and there can be no doubt a much larger fall took place at both those places on that day. I have not asked for any observations from the Queen's College at Galway, but I know from a publication I have before me that the fall recorded there on that day was 4.93 ins., being the largest 24 hours' fall ever recorded at any station in the United Kingdom during 1887.

There are three gauges in the neighbourhood of Tuam. I have a report from two of them; the other observer did not answer my letter to him. The observer, who was good enough to send me a report, has two gauges working at his place. He was, unfortunately, absent from home on the morning of September 2nd, 1887, and his son, whom he left in charge of his gauges, did not measure the rain they contained till the morning of the 3rd, when one gauge, six feet above the ground, was found to hold 2.910 ins., and the other, which is one foot above the ground, contained 2.965 ins. He reports: "Only a few showers fell after 4 a.m. on September 2nd, so that the fall for the 24 hours ending at 9 a.m. on the 2nd would be about 2.75 ins. The rain began about 1 p.m. on the 1st. It was the largest 24 hours' fall on record in the neighbourhood of Tuam.

I have received two reports from West Galway. One station (Kylemore House), is five miles east of the town of Letterfrack. Here the rainfall was .85 in.

At Kylemore Castle, which is about two miles east of the town of Letterfrack, the fall was 1.55 in.

I have made many inquiries after other stations in Galway; but, as far as I know, there are none except the ones above mentioned.

REMARKABLE DISPLAY OF LIGHTNING IN THE NEW ENGLAND DISTRICT, NEW SOUTH WALES, DECEMBER 1888. (Extract of a letter received by G. M. WHIPPLE, F.R.A.S.)

DEAR SIR,—It may interest you if I tell you of a phenomenon I witnessed on my voyage out from England to Australia. When about eight days out, as we neared Las Palmas, in the Canary Islands, we experienced a very violent storm of lightning and rain. From about sundown to the "wee sma' hours" of the morning the lightning was flashing almost without cessation and at all points of the com-

pass. The electric fluid, too, was constantly playing on the conductors placed in the rigging, and was running in a blue stream of liquid fire down into the water, and so lost.

The sight was altogether so weird and attractive that I did not go below all night, but remained on deck to watch it, and presently I observed a particularly bright flash of forked lightning with three branches, followed instantly by a flash of sheet lightning; and the effect I wish to draw your attention to was this, that the first, or forked, flash stood out in *black* upon the background of sheet lightning, the image of the first not having yet left the retina of the eye.

May I suggest as the solution of the mystery of the dark flash in the photograph, that while the exposure takes place, a similar combination occurs, and the plate registers the effect in the same way as did my eyes?

While I am on the subject of lightning I will relate another experience of mine.

About the middle of December, 1888, my wife and I were travelling on horse-back from Grafton, on the Clarence River, to Glean Innes, in the New England district, a distance of 116½ miles, and as we had for some few weeks been having very hot weather, the glass registering 115° in the shade, we encountered on the road very severe thunderstorms on each day as a natural result, the weather having taken a turn on the very day upon which we started.

Our road lay for at least 88 miles across a chain of mountains, and each day at about 3 or 4 p.m. the storm clouds would rise rapidly above the mountain peaks, and we would pursue our journey to the accompaniment of about the most violent thunderstorms it has ever been my lot to meet; the rain also descending in torrents. We had a grand opportunity of seeing whence the Clarence River receives a great amount of its water, for we passed over or along no less than six of its tributaries.

On the afternoon of the third day, at about 1.30 p.m., we left the "bark humpy," the dwelling-place of one of the Government road caretakers and his wife, where we had rested for an hour and a half and had some refreshment, to pursue our journey to our resting-place for the night, about 25 miles away. At a distance of 8 miles from this house we began to rise on to the New England table-land by means of a road cut out on the mountain side. At the foot of this we were already about 1,000 ft. above the sea level, and we had to rise 4,000 ft. in one continuous ascent of 7 miles.

When about one mile from the top we saw that the usual storm was on us—it was coming from that point of the compass to which we were travelling—and we therefore drew back a little and so had a very slight shelter from the first blast of the storm, being slightly defended by the spur of the mountain round which we had been about to go. We, of course, dismounted, for the road was not more than wide enough for ox and horses teams to traverse, and so prepared to face the worst.

My wife at first sought the shelter, if it could be called so, of the side of the cutting or notch, while I held the two horses by hempen halters under their bridles. The storm introduced itself by striking a tree about 20 yards away from and above us; the next flash came just over my left shoulder, between my wife and myself, being, of course, simultaneously accompanied by thunder. This so terrified the horses that they pulled at me to such an extent that I yielded inch by inch until their houghs were projecting over the edge of the precipice; until just then I was able to get a grip of the road, so that they could pull me no further. From this time on for about 10 minutes we had the hottest time I hope ever to encounter. The lightning played incessantly, and the thunder crashed and rolled and was reverberated by the mountain peaks; altogether the matter was most awe-inspiring. We however kept cool, for there was no good in fearing, and stood our ground. You must understand we were *in* the cloud; the lightning flashing *above, around, beneath* us and *between* us. Once, after a more awful flash and crash than others, the horses swung round quickly, whirling me off my feet and round *over* the edge and back again on the other side of them. When my wife saw the great danger I ran if they should repeat this, she came out from her shelter (?) and took my whip, and with it cut the poor animals, and made them get close against the side of the cutting, and stood then between them and the edge so that they should not repeat the

operation. While she stood so close against one of them about a foot away a flash of lightning passed *between* her and the horse and past me, so that we felt the hot wind of it; it singed the hair on her head and on the horse's side, but did not injure any of us. Our bits and stirrup-irons were some white metal, and others good honest *rusty* iron.

Presently a flash passed over the edge and below where we stood, and the next one was on the next spur of the mountain, and so the danger had providentially passed away.

We had still 11 miles to go for shelter, wet through as we were, and happily we got there all right and none the worse for our encounter with the elements.

While I say that we would not fight shy of the journey again if the occasion arose, we yet would not care to undertake it under similar circumstances, for one such experience is enough for an ordinary lifetime.

If this relation interests you at all I shall be glad of a line to that effect, as, although we are absolute strangers, I shall be pleased if I have been able to give any information on the wonderful subject of the erratic course of lightning.

I pledge you my word as to the truth of the relation, and trust you will accept it as authentic.

I am, dear Sir,
Yours faithfully,
A. THORPE.

68 Bull Street, Newcastle, New South Wales,
October 15th, 1889.

FOUNDATION OF A MEDAL FOR METEOROLOGICAL PHOTOGRAPHY.

At the Meeting of the Society on December 18th, 1889, the Foreign Secretary announced that he had recently received from the Société Météorologique de France the conditions of competition for the Medals founded by M. Janssen, as announced at the Meeting of the French Society on February 7th, 1888.

A Gilt Medal will be awarded every year, and a Gold Medal every five years for the work of most merit.

The adjudicators will be nominated by the Société Météorologique de France.

The precise questions which are recommended for study are given in a printed circular, a copy of which can be obtained from the Secretary of the French Society, 7 Rue des Grands-Augustins, Paris.

RECENT PUBLICATIONS.

AMERICAN METEOROLOGICAL JOURNAL. October-December 1889. Vol. VI.
Nos. 6-8. 8vo.

Contains:—The determination of the amount of rainfall, by Prof. Cleveland Abbe (8 pp.).—State Tornado Charts, by Lieut. J. P. Finley (25 pp.). The States dealt with are Louisiana, Texas, Arkansas, North Carolina, Dakota, and Indiana.—Distribution of average wind velocities in the United States, by Dr. F. Waldo (42 pp.).—Theory of Storms, based on Redfield's laws, by H. Faye (12 pp.).—Meteorology at the Paris Exhibition, by A. L. Rotch (14 pp.). This is an account of the meteorological instruments shown at the Exhibition. The meteorological display was disappointing, since neither England nor Germany contributed to it. The only Governments represented were France and the United States.—Ferrel's Convectional Theory of Tornadoes, by W. M. Davis and C. E. Curry (13 pp.).

A POPULAR TREATISE ON THE WINDS: comprising the General Motions of the Atmosphere, Monsoons, Cyclones, Tornadoes, Waterspouts, Hailstorms, etc. By WILLIAM FERREL, M.A., Ph. D. 8vo. 1889. 505 pp.

In the preface the author says:—"Since the middle of the present century great advances have been made in meteorology, especially in the study of the mechanics of the atmosphere. Before this epoch little was known even with regard to the

general motions of the atmosphere ; the true theories of cyclones, tornadoes, waterspouts, hailstorms, cloud-bursts, etc. were entirely unknown, and the observed phenomena were mostly regarded as mysteries. Although there are still some things which require more study and further explanation, yet these subjects have now become much clearer and better understood ; and so great has the change been that the recent advances are often called the 'new meteorology.' During this period of advancement the author has written a number of meteorological papers in an endeavour to advance our knowledge in the subjects mentioned above. These papers, however, were written in a very mathematical manner, and consequently could only be understood by a few readers. In the present work the author has endeavoured to give a more popular presentation of his views, with but few mathematical expressions. The work is divided into eight chapters, viz. (1) Constitution and nature of the atmosphere ; (2) Motion of bodies relative to the earth's surface ; (3) General circulation of the atmosphere ; (4) Climatic influences of the general circulation ; (5) Monsoons, and land and sea breezes ; (6) Cyclones ; (7) Tornadoes ; and (8) Thunderstorms.

JOURNAL OF THE ASIATIC SOCIETY OF BENGAL. Vol. LVIII. Part II. 1889. 8vo.

Contains :—The tornadoes and hailstorms of April and May 1888 in the Doab and Rohilkhand, by S. A. Hill, B. Sc. (48 pp. and 6 plates). The peculiar and distinctive feature of the three most important storms of this period was the extraordinary destructive character of the accompanying hail, which, owing either to the immense size of the hailstones and the velocity with which they fell, or to the great quantity of the hail and the low temperature it caused, was most unusually fatal to human and animal life, as well as destructive to crops and trees.

JOURNAL OF THE SCOTTISH METEOROLOGICAL SOCIETY. Vol. VIII. Third Series. No. VI. 8vo. 1889.

Contains, among other information, the following papers :—On Meldrum's Rules for handling Ships in the Hurricanes of the Southern Indian Ocean ; with Researches on the nature of Hurricanes generally, by the Hon. R. Abercromby (34 pp.). The author gives the results of his own investigations, and develops the explanations which have been partially given by Meldrum. Comparing the revised rules with the older ones, the author remarks :—(1) That the rule for finding approximately the bearing of the vortex is modified and improved by the addition of indications derived from clouds, but that still the position of the vortex cannot be determined nearly so accurately as was formerly supposed. (2) That the great rules of the "laying-to" tacks remain unaltered. (3) That the greatest improvement is in recognising the position and nature of the belt of intensified trade wind outside the true storm field of a cyclone, where a ship experiences increasing wind without change of direction, with a falling barometer. The old idea that such conditions show that a vessel is then necessarily on the line of advance of a hurricane is erroneous. She may, but she need not be ; and under no circumstances should she run till the barometer has fallen at least $\frac{1}{10}$ th inch. (4) There are certain rules which hold for all hurricanes ; but every district has a special series, due to its own local peculiarities. Finally, no one should blame the master of a ship for not following the established rules without the closest investigation ; for, as Piddington says, "absolute rules are all nonsense," and much depends upon the capabilities of a ship and on the ever-varying conditions of a heavy cross sea.—The Temperature of the Surface of the Sea on the East Coast of Scotland, by H. N. Dickson (17 pp.). It appears that the mean annual temperature of the surface of the sea on the east coast is $47^{\circ}2$, except to the south of the Firth of Forth, where it may be taken as $47^{\circ}8$. No progressive change is observable, the means at Wick and Burntisland being identical, and all the intermediate stations coinciding to within $0^{\circ}4$. To the west of the Orkneys and in the Shetland Islands the mean is over 48° . There are two masses of water—one on the north side of the Moray Firth, between Helmsdale and Wick, and another off the Aberdeenshire coast,—both of which are in every way less sensible to changes of temperature than the water in the surrounding districts. It seems obvious that in these two places water wells up to the surface from below.—Weather Folk-Lore of Scottish Fishermen, by H. N.

Dickson (6 pp.). This is a collection of local weather sayings current among fishermen, which the author has collected while inspecting the Fishery barometers of the Meteorological Council.

METEOROLOGISCHE ZEITSCHRIFT. Redigirt von Dr. J. HANN und Dr. W. KÖPPEN. September to December 1889. 4to.

Contains :—Beiträge zur arktischen Meteorologie, von Dr. J. Hann (9 pp.). This is a summary of Parts IV. and V. of the *Contributions to our Knowledge of the Meteorology of the Arctic Regions*, published by the Meteorological Office. Dr. Hann speaks in high terms of the work of Mr. Strachan, and expresses his surprise that the work has not attracted more attention in England.—Der Krakatau-Ausbruch und seine Folge-Erscheinungen, von Dr. J. M. Pernter (38 pp.). This is a summary of the Krakatoa Report of the Royal Society, and deals with the geological and optical sections, and those on the sound and air and sea-waves.—Die wissenschaftlichen Erhebungen zur Wasserkatastrophe in der sächsischen Oberlausitz am 18 Mai 1887, von Dr. O. Birkner (7 pp. and plate). The author attributes the flood to the contour of the country, which caused a certain thunder-cloud to hang about the particular valleys and cause excessive rainfall of about six inches in the 24 hours. The destructive action of the water was aggravated by the fact of the country having been cleared of forest. Dr. Birkner recommends the inhabitants of the district which has suffered from floods to plant trees extensively, and especially to encourage growth of underwood on the sides of brooks.—Einige Anomalien in den Winden des nördlichen Indiens und ihre Beziehung zur Druckvertheilung, nach S. A. Hill (16 pp. and 2 plates). This is an abstract of Mr. Hill's paper in the *Philosophical Transactions*.—Zur Theorie des Bishop'schen Ringes, von Dr. J. M. Pernter (8 pp.). This is a criticism, *inter alia*, of the varying results from the diameter of the water particles producing Bishop's ring given respectively by Flögel, Forel, and Archibald; and the paper concludes with the hope that a set of measurements of solar and lunar coronæ will be undertaken, as our knowledge of the condition of the water suspended in the air is still very defective.—Wolkenformen und Wolkenbilder, von Prof. H. H. Hildebrandsson (7 pp.). This is a reproduction of the author's paper before the Congress in Paris, and concludes with a notice of the new Cloud Atlas.

QUEENSLAND METEOROLOGICAL REPORT FOR 1887. By CLEMENT L. WRAGGE, Government Meteorologist. 4to. 1889. 129 pp. and numerous plates.

This being the first Annual Report of the Meteorological Branch of the Post and Telegraph Department, Mr. Wragge gives a full account of the organisation of the system and details *in extenso* the steps taken to prepare rules, inspect stations, &c. The stations are equipped in accordance with the recommendations of the Royal Meteorological Society.

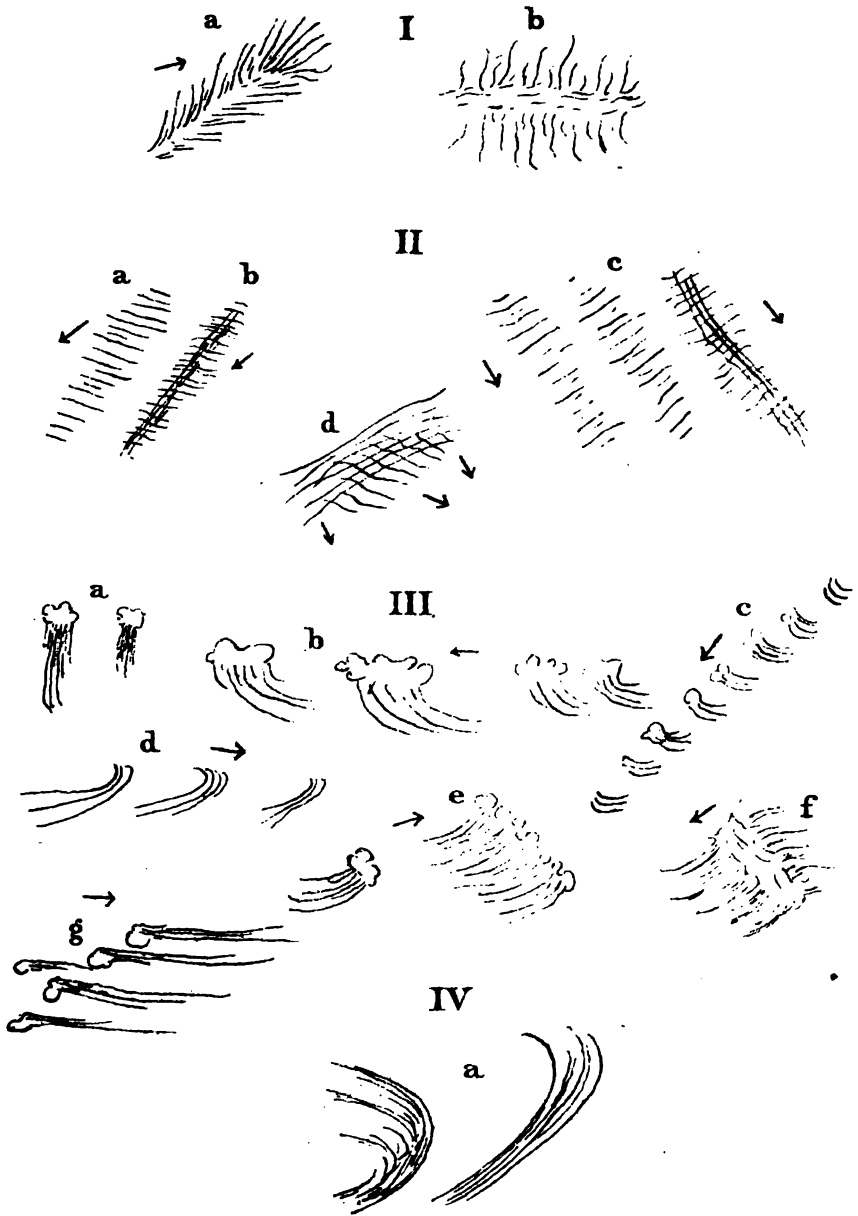
SYMONS'S MONTHLY METEOROLOGICAL MAGAZINE. October to December 1889. 8vo.

The principal contents are : The determination of the amount of rainfall, by Prof. Cleveland Abbe (6 pp.). This paper was read at the British Association meeting at Newcastle-on-Tyne.—Autumn Congresses (13 pp.). This is a brief summary of the meteorological reports and papers read at the recent meetings of the British Association, the Congrès International Météorologique, the Sanitary Institute, and the Congrès International d'Hydrologie et de Climatologie.—The floating island in Lake Derwentwater, by Prof. R. Meldola, F.R.S. (3 pp.).—On the black bulb thermometer *in vacuo*, by Prof. H. McLeod, F.R.S. (2 pp.).

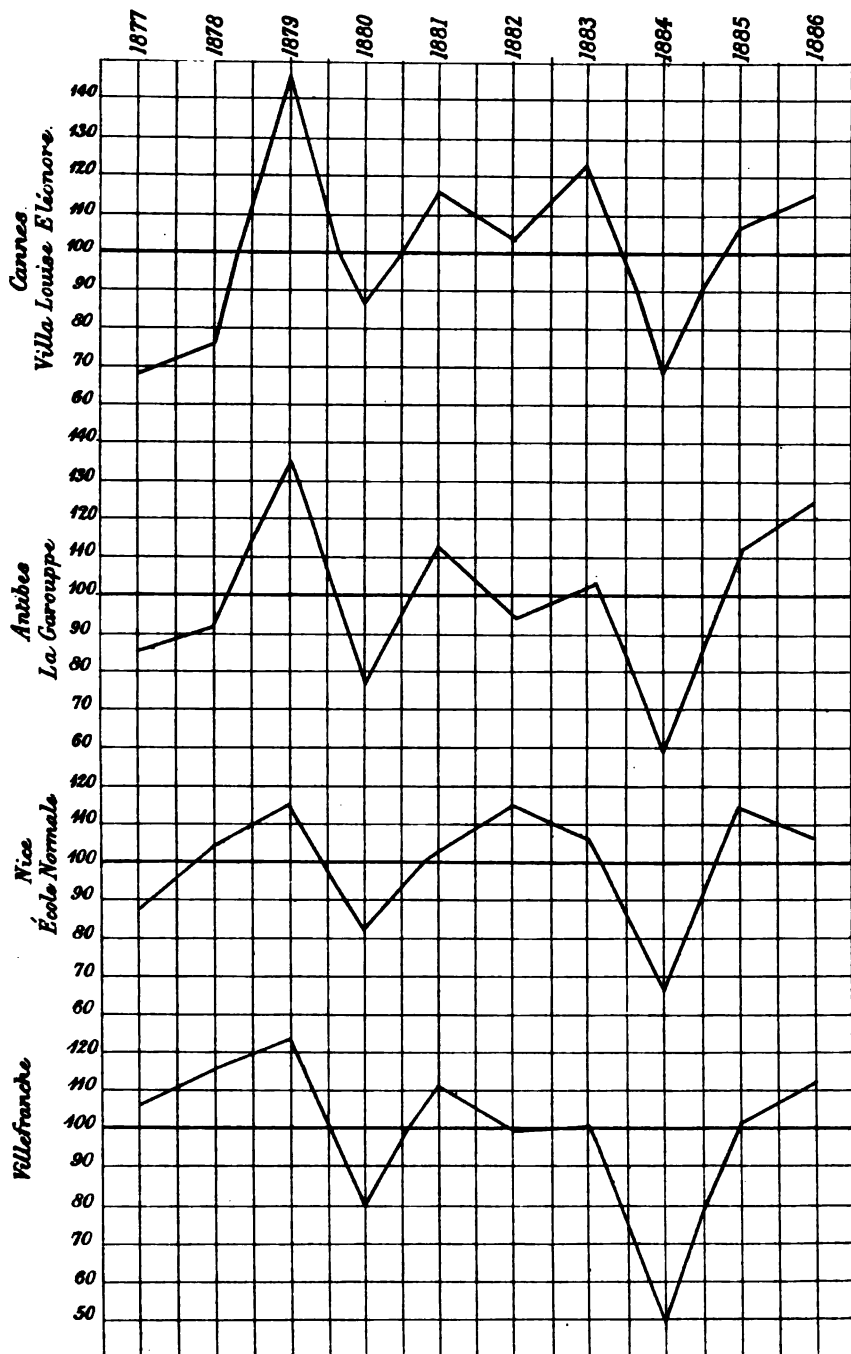
THE OCEAN OF AIR. METEOROLOGY FOR BEGINNERS. By AGNES GIBERNE. With a Preface by the Rev. C. Pritchard, D.D., F.R.S. 8vo. 1890. 840 pp.

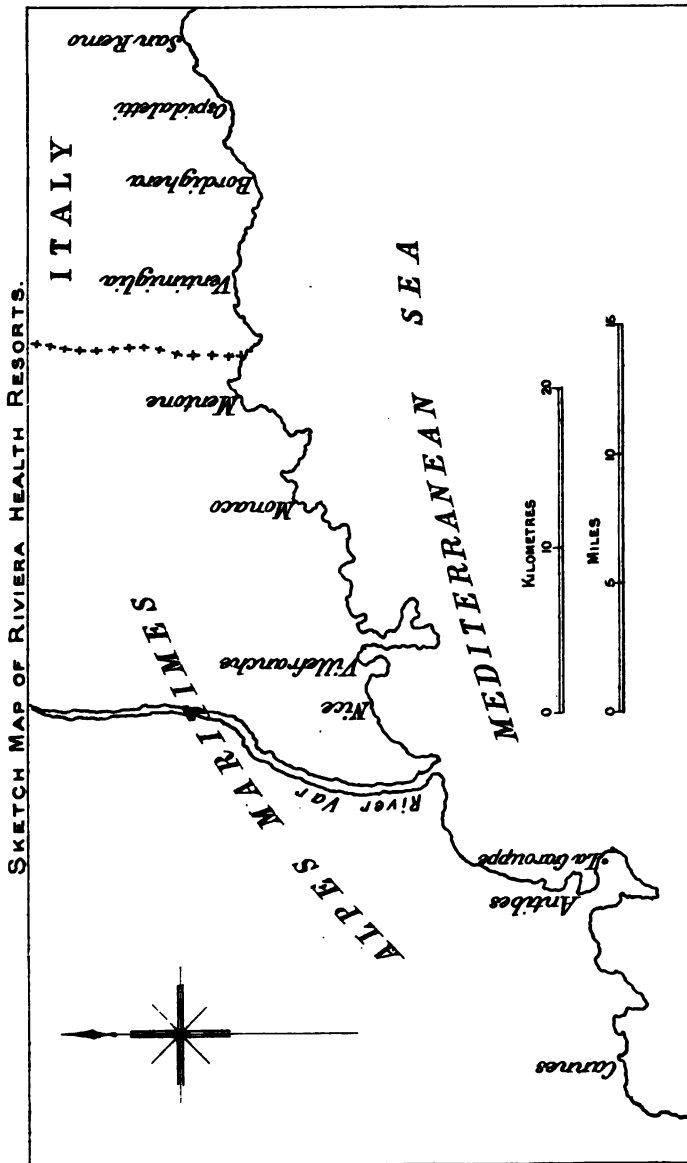
This is a very pleasantly written book dealing in an elementary manner with the Atmosphere, and is, in fact, as stated on the title page, "Meteorology for Beginners." The work is divided into 8 parts, which treat of the uses, gases, vapours, movements, disturbances, forces of, and life in, the air-ocean. The value of the book is increased by 16 plates engraved from instantaneous photographs.

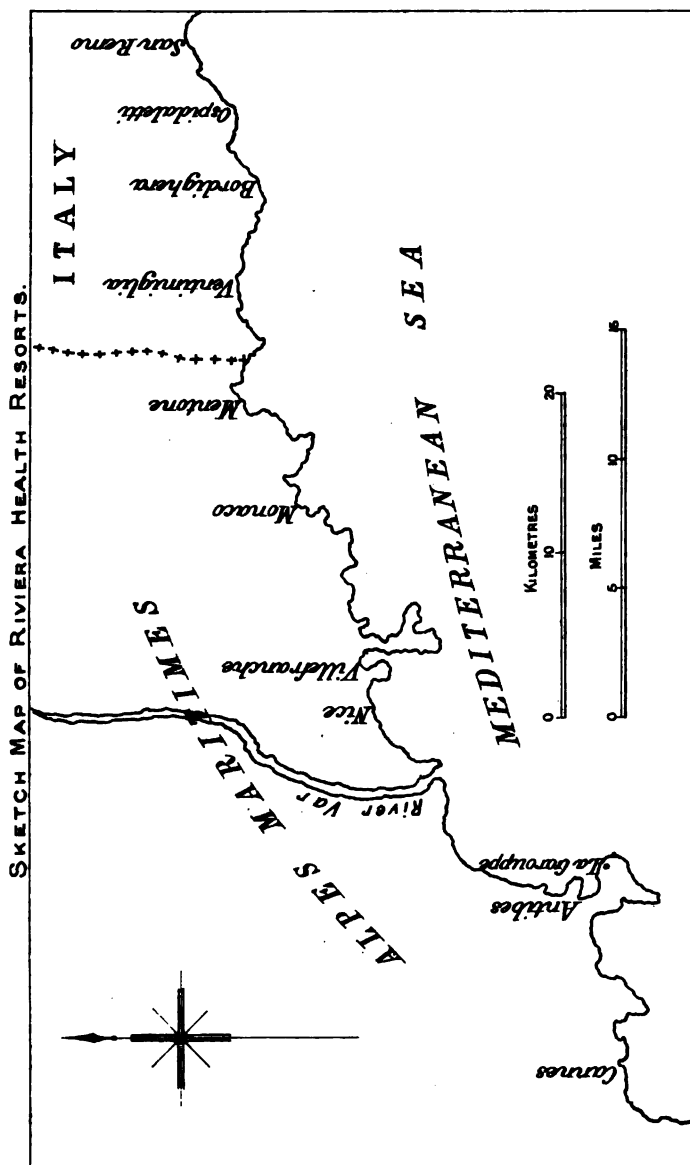
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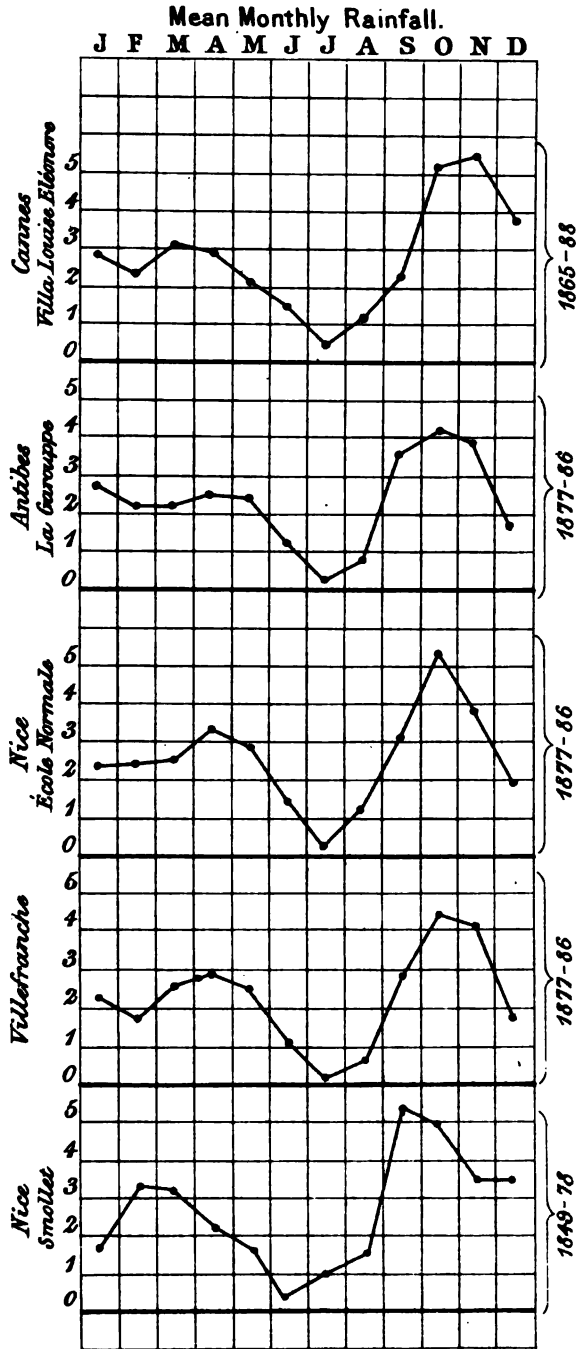


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Quarterly Journal

OF THE

ROYAL

METEOROLOGICAL

SOCIETY.

EDITED BY A
COMMITTEE OF THE COUNCIL.

APRIL 1890.

VOL. XVI. No. 74.

W B LONDON:
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Royal Meteorological Society.

ESTABLISHED 1850. INCORPORATED BY ROYAL CHARTER, 1866.

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SESSION 1890.

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JUN 20 1890

QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY

VOL. XVI.

APRIL 1890.

No. 74.

ON ATMOSPHERIC DUST.

An Address delivered to the Royal Meteorological Society, January 15th,
1890.

By WILLIAM MARCET, M.D., F.R.S., PRESIDENT.

THE infinitely small particles of matter we call *dust*, though possessed of a form and structure which escape the naked eye, play, as you are doubtless aware, important parts in the phenomena of nature. A certain kind of dust has the power of decomposing organic bodies, and bringing about in them definite changes known as putrefaction, while other kinds exert a baneful influence on health and act as sources of infectious diseases. Again, from its lightness and extreme mobility, dust is a means of scattering solid matter over the earth. It will float in the atmosphere as mud does in water, and blown by the wind, may perhaps travel thousands of miles before again alighting on the earth. Thus Ehrenberg, in 1828, detected in the air of Berlin the presence of organisms belonging to African regions, and he found in the air of Portugal fragments of *infusoria* from the steppes of America. The smoke of the burning of Chicago was, according to Mr. Clarence King (Director of the United States Geological Survey), seen on the Pacific coast.

Dust is concerned in many interesting meteorological phenomena; such as

NEW SERIES.—VOL. XVI. F

fogs, as it is generally admitted that fogs are due to the deposit of moisture on atmospheric motes. Again, the scattering of light depends on the presence of dust, and you may remember my showing you on a former occasion the beautiful experiment of Tyndall's, illustrating the disappearance of a ray of light when made to travel through a glass receiver free from dust, and its re-appearance as soon as dust was admitted into the vessel. There is no atmosphere without dust, although the amount varies largely, from the summit of the highest mountain where the least is found, to the low plains, at the seaside level, where it occurs in the largest quantities.

The origin of dust may be looked upon, without exaggeration, as universal. Trees shed their bark and leaves, which in dry weather are powdered and carried about by ever varying currents of air, plants dry up and crumble into dust, the skin of man and animal is constantly shedding a dusty material of a scaly form. The ground in dry weather, high roads under a midsummer's sun, emit clouds of dust consisting of very fine particles of earth. The fine river and desert sand, a species of dust, is silica ground down into a fine powder under the action of water.

If the vegetable and mineral world crumbles into *dust*, on the other hand it is highly probable that dust was the original state of matter before the earth and heavenly bodies were formed; but here we enter the region of theory and probabilities. In a science like meteorology, where a wide door is open to speculation, we should avoid as much as possible stepping out of the track of known facts; still there is a limit to physical observation, and in some cases we can do no more than glance into the possible or probable source of natural phenomena. Are we on this account to give up inquiring for *causes*? This question I shall beg to leave you to decide, but where we have such an experienced authority as Norman Lockyer, I think the weight attached to possibilities and theories is sufficiently great to warrant my drawing your attention for a few moments to the probable origin of the stars and of our earth.

I daresay many of you have read the interesting article in the *Nineteenth Century* of November last, by Norman Lockyer, and entitled "The History of a Star." The author proposes to clear in our imagination a limited part of space, and then set possible causes to work; that dark void will sooner or later be filled with some form of matter so fine that it is impossible to give it a chemical name, but the matter will eventually condense into a kind of dust mixed with hydrogen gas, and will constitute what are called *nebulae*. These nebulae are found by spectrum analysis to be made up of known substances, which are magnesium, carbon, oxygen, iron, silicon, and sulphur. Fortunately for persons interested in such inquiries, this dust comes down to us in a tangible form. Not only have we dust shed from the sky on the earth, but large masses, magnificent specimens of meteorites which have fallen from the heavens at different times, some of them weighing tons, may be submitted to examination. From the spectroscopic analysis of the dust of meteorites we find that in addition to hydrogen their chief constituents are magnesium, iron, silicon, oxygen and sulphur.

There are swarms of atoms of dust travelling through space, and their motion may be extremely rapid. We know, for instance, some stars to be moving so quickly that from Sir Robert Ball's calculations one among them would travel from London to Pekin in something like two minutes. From photographs taken of the stars and nebulae, we are entitled to conclude that the swarms of dust meet and interlace with each other, becoming raised to a very high temperature by friction and collision, and giving rise to what look like stars. The light would last so long as the swarms collide, but would go out should the collision fail; or, again, such a source of supply of heat may be withdrawn by the complete passage of one stream of dust-swarms through another. We shall, therefore, have various bodies in the heavens, suddenly or gradually increasing or decreasing in brightness, quite irregularly, unlike those other bodies where we get a periodical variation in consequence of the revolution of one of them round the other. Hence, as Norman Lockyer expresses it clearly, "It cannot be too strongly insisted upon, that the chief among the new ideas introduced by the recent work is that a great many stars are not stars like the sun, but simply collections of meteorites, the particles of which may be probably thirty, forty, or fifty miles apart."

The swarms of dust referred to above undergo condensation by attraction or gravitation; they will become hotter and brighter as their volume decreases, and will pass from being nebulae to being what we call true stars.

The author of the paper I am quoting from imagines such condensed masses of meteoric dust being pelted or bombarded by meteoric material, producing heat and light, which effect will continue so long as the pelting is kept up. To this circumstance is due the formation of stars like suns. Our earth originally belonged to that class of heavenly bodies, but from a subsequent process of cooling assumed its present character.

While apologising for this digression into extra-atmospheric dust, I shall propose to divide atmospheric dust into *organic*, or *combustible*, and *mineral*, or *incombustible*. The dust scattered everywhere in the atmosphere, and which is lighted up in a sunbeam, or in a ray from the electric lamp, is of an organic nature. It is seen to consist of countless motes, rising, falling, or gyrating, although it is impossible to follow any of them with the eye for longer than a fraction of a second. We conclude that their weight exceeds but very slightly that of the air, and, moreover, that the atmosphere is the seat of multitudes of minute currents, assuming all kinds of directions. Similar currents, though on a much larger scale, are also met with in the air. One day last June, from the top of Eiffel's Tower in Paris, I amused myself throwing an unfolded newspaper over the rail carried round the summit of the tower. At first it fell slowly, carried away by a light breeze, but presently it rose, and describing a curve, began again to fall. As it was vanishing from sight the paper appeared to me as if arrested now and then in its descent, perhaps undergoing again a slight upheaval. Here was indeed a gigantic mote floating in the atmosphere, and subject to the same physical laws, though on a larger scale, as those delicate filaments of dust we see dancing merrily in a sunbeam.

I recollect witnessing, at one of the Friday evening lectures of the Royal Institution in the year 1870, the following beautiful experiment of Dr. Tyndall, illustrative of the properties of atmospheric dust:—If we place the flame of a spirit lamp or a red-hot metal ball in the track of a beam of light, there will be seen masses of dark shadows resembling smoke emitted in all directions from the source of heat. At first sight this appears as if due to the dust particles being burnt into smoke; but by substituting for the spirit flame or red-hot metal ball an object heated to a temperature too low to burn the motes, the same appearance of smoke is observed, hence the phenomenon is not owing to the combustion of the dust. The explanation, however, is obvious. The source of heat, by warming the air in its contact and immediate proximity, made the air lighter and the motes relatively heavier, consequently they fell, and left spaces free from dust. These spaces in the track of the electric ray appeared dark, or looked as if full of a dense smoke, because, from the absence of dust, the light of the ray could no longer be scattered in them.

The motes were next examined by Tyndall, to determine whether they were organic or mineral. This was done by driving a slow current of air through a platinum tube heated to redness, and examining this air afterwards in a beam of light; it was then found to darken the ray, having lost the power of scattering light; therefore the dust had been destroyed or burnt by passing through the red hot platinum tube, clearly showing its organic nature.

We inhale into our lungs day and night this very finely-divided dust, and yet it produces no ill effect, no bronchial irritation. Tyndall has again shown by the analytical power of a ray of light what becomes of the motes we inhale.

Allow me to return to the experiment with the red-hot metal ball placed in the beam of the electric light. Should a person breathe on the heated ball, the dark smoke hovering around it will at first disappear, but it will reappear in the last portions of the air expired. What does this mean? It means that the first portions of air expired from the lungs contain the atmospheric motes inhaled, but that the last portions, after reaching the deepest recesses in the organs of respiration, have deposited there the dust they contained.

It is difficult to say how much of the dust present in the air may become a source of disease, and how much is innocuous. Many of the motes belong to the class of *micro-organisms*, and the experiment to which we have just referred shows how easily these micro-organisms, or sources of infectious diseases, can reach the lungs and do mischief if they should find a condition of the body upon which they are able to thrive and reproduce themselves. Atmospheric motes, although it has been shown that they are really deposited in the respiratory organs, do not accumulate in the lungs and air passages, but undergo decomposition and disappear in the circulation. Smoke, which is finely-divided coal dust, is clearly subjected to such a destructive process; otherwise the smoky atmosphere of many of our towns would soon prove fatal, and tobacco smoke would leave a deposit interfering seriously with the phenomena of respiration after a very short time.

Dust, however, in its physical aspect is far from being always innocuous, and, as you are aware, many trades are liable to suffer from it. The cutting of chaff, for horses' food, is one of the most pernicious occupations, as it generates clouds of dust of an essentially penetrating character. Those engaged in needle manufactures and steel grinders suffer much from the dust of metallic particles. Stone cutters, and workmen in plaster of Paris, coal heavers, cotton and hemp spinners are also engaged in trades injurious to health because of the dust these men unavoidably work in. Those engaged in cigar and rope manufactures, or in flour mills, hat and carpet manufacturers, are also liable to suffer for the same reason. A number of methods have been adopted, more or less successfully, to rid these trades of the danger due to the presence of dust. I shall not detain you on this subject, which would carry me too far, but merely bring to your notice the fact I observed many years ago, that charcoal has the power of retaining dust in a remarkable degree. I have had charcoal respirators made of such a form as to cover both the mouth and nose, and containing about $\frac{1}{4}$ inch thick of charcoal in a granular state. I could breathe through such a respirator in the thickest cloud of dust made by chaff cutting without being conscious of inhaling any of the dust.

The subject of micro-organisms belongs to the science known as micro-biology. As meteorologists we are chiefly concerned with their distribution in the atmosphere. Micro-organisms are dust-like particles capable of cultivation or reproduction in certain media and at certain temperatures. If a particle of matter known to contain micro-organisms, also called *bacilli*, be placed on a clear surface of gelatine and maintained at a temperature favourable to their development, in a short time the gelatine will be found to contain a colony of those same *bacilli*. A fact so often stated as to become a medical truism is that there can be no infectious disease without the presence of the micro-organism special to that disease. Open cesspools, putrid meat or vegetable matter, accumulations of refuse have no ill effects on health unless the micro-organism of a certain disease, as those of typhoid fever or cholera, be present. On such foul decomposing matters these organisms thrive. They are reproduced with great activity, and become virulent in their effects.

Micro-organisms are scattered everywhere in the atmosphere. Dr. Miquel, at the Montsouris Observatory at Paris, has made an extensive inquiry into their distribution in air and water. In this country Dr. Percy Frankland has, with praiseworthy labour and perseverance, investigated the subject of micro-organisms, and ascertained their number in various localities. The result of his inquiry is that in cold weather, especially when the ground is covered with snow, the number of organisms in the air is very much reduced, and presents a very striking contrast with that found in warmer weather. The experiments made on a March day show that during cold and dry weather, with a strong East wind blowing over London, a large number of micro-organisms may still be present in the air. It is particularly noticeable that even after an exceedingly heavy rain, and within a few hours afterwards, the number of micro-organisms in the air should be as abundant as usual.

Taking an average of the experiments made on the roof of the Science Schools of the South Kensington Museum, the mean number of organisms found in 10 litres of air amounted to 85, while an average of 279 fell on one square foot in one minute. Other experiments made near Reigate and in the vicinity of Norwich present a marked contrast with those undertaken in the South Kensington Museum. There was a remarkable freedom from micro-organisms of the air collected on the heath near Norwich during comparatively warm April weather, when the ground was dry. The air in gardens at Norwich and Reigate was richer in micro-organisms than that of the open country. Again, the number of organisms found in the air of Kensington Gardens, Hyde Park, and Primrose Hill was less than in that taken from the roof at South Kensington, but greater than in the country.

Experiments made in enclosed places, where there is little or no aerial commotion, show the number of suspended organisms to be very moderate, but as soon as any disturbance in the air occurs, from draughts or people moving about, the number rapidly increases and may become very great. Experiments made in a railway carriage afford a striking example of the enormous number of micro-organisms which become suspended in the air when many persons are brought together.

Micro-organisms being slightly heavier than air, have an invariable tendency to fall, and on that account frequently collect on the surface of water; hence rivers, lakes and ponds are constantly being thus contaminated. Micro-organisms in very pure water are not readily disposed to multiply, but traces of decomposing organic matter will induce their reproduction. One remarkable case occurs to me illustrating this fact. In 1884 a severe epidemic of typhoid fever broke out in the City of Geneva. The water of the lake in the harbour, which is surrounded by houses on three sides, was then examined by a distinguished micro-biologist, M. Fol, who discovered it to be full of micro-organisms; the water supplied to the town for drinking purposes was taken from the River Rhône immediately as it flowed out of the harbour. The inquiry was pursued further, and it was found that just outside the harbour, on the surface of the water, there were still a number of micro-organisms, though less than in the harbour; but a few feet below the surface, say 8 or 4 feet, they had greatly diminished in number, indeed to such an extent that there were very few present. The obvious remedy was at once carried out. A wooden aqueduct was constructed, opening into the lake about 150 yards outside the harbour, and some 8 or 4 feet under the surface. As stated by Dr. Dunant, a Geneva physician who has given a very interesting account of this epidemic,¹ eighteen days after the source of the water-supply had thus been altered, a marked decline took place in the epidemic, and it was clearly being mastered. A similar epidemic, due to a like cause, occurred about the same time at Zurich.

There is one point connected with the properties of dust of organic origin

¹ Epidémie de fièvre Typhoïde à Genève en 1884, par P. L. Dunant, *Revue Médicale de la Suisse Romande*, 1887.

which I think cannot fail to be of interest. I mean its inflammability, and its liability to explode when mixed with air. By *explosion* is meant that the propagation of flame by a very finely-divided material such as coal dust, mixed in due proportion with air, may proceed with a rapidity approaching the transmission of explosion by a gaseous mixture.

An interesting lecture was delivered on this subject at the Royal Institution, in April 1882, by Sir Frederick Abel, entitled "Some of the dangerous properties of dust." The lecturer refers to instances of explosions in flour-mills, due in all probability to a spark from the grinding mill-stones, occurring in consequence of a deficient supply of grain to the stones.

Messrs. Franklin and Macadam, who investigated the subject, found that accidents of this nature were of frequent occurrence. In May 1878 a flour-mill explosion, quite unparalleled for its destructive effects, occurred at Minneapolis, Minnesota. Eighteen lives were lost, and six distinct corn mills were destroyed. Persons who were in proximity to the scene of the calamity heard a succession of sharp hissing sounds, doubtless caused by the very rapid spread of flame through the dust-laden air of the passages inside the mill. The nearest mill to that first fired was 25 feet distance, and exploded as soon as the flames burst through the first mill. The explosion of the third mill, 25 feet from the second, followed almost immediately; and the other three mills, about 150 feet distance in another direction, were at once fired. The fire was attributed to a spark from friction of the mill-stones.

Coal dust in coal mines is a cause of accident from explosions, which has been closely investigated in this country, in Germany and other mining districts. Sir Frederick Abel has given this subject especial attention, and brings it prominently forward in his valuable and exhaustive paper on "Accidents in Mines," read at the Institution of Civil Engineers in 1888. Some mines are, of course, more dusty than others, and coal dusts are not all equally inflammable. That which is deposited upon the sides, top timbers, and ledges in a dry, dusty mine-way, is much finer and more inflammable than the coarser dust which covers the floors. The lecture I have referred to alludes to the case of a considerable quantity of coal dust accidentally thrown over some screens at a pit-mouth bursting into flame as the dust cloud came into contact with a neighbouring fire, and burning a man very severely. There appears good ground for believing that fire may travel to a considerable extent through the workings of a mine from the ignition of coal dust, as will be seen in the following account, extracted from Messrs. W. N. and J. B. Atkinson's book on *Explosions in Mines*:—"An appalling accident happened at the Seaham Colliery, in the County of Durham, on the 8th September, 1880, at 2.20 a.m., causing the death of 24 men. An explosion occurred in the mine, and a loud report was heard at the surface, accompanied with a cloud of dust from the shaft, but no fire was seen. Owing to damage to the shaft it was more than twelve hours before a descent could be effected, and then a scene of destruction was witnessed by the explorers. Doors and air-crossings destroyed; tubs broken to pieces, and hurled one over the other; timber blown out, attended with heavy falls from the roof; and the bodies of men

and horses in many cases terribly mutilated. The explosion was found to have extended over roads of an aggregate length of about 7,500 yards, the greatest distance between the extreme points reached being about 8,800 yards."

When discussing the cause of this terrible accident Messrs. Atkinson remark that it was apparently impossible to account for the effects of the explosion on the assumption that it was due to fire-damp, as the presence of fire-damp was most unlikely to occur at any part at which the explosion could have happened; and, therefore, attention must be turned to coal dust. There was coal dust on all the roads traversed by the explosion, and there was coal dust at the supposed point of origin. These facts are of striking significance. After the explosion, all parts of the mine in which its effects could be traced were covered on the bottom and on flat surfaces with a coating of fine dust, which, when examined under the microscope, appeared to have been acted on by great heat. This fine dust covered the surface for a depth of from $\frac{1}{8}$ to $\frac{1}{4}$ an inch and under. Dust of this kind was entirely absent on those roads over which the explosion had not extended. With reference to the original ignition, a shot had been fired apparently simultaneously with the explosion. The road at the place was of stone, and would probably be coated with the finest coal dust; and, moreover, just above the spot where the fatal shot was fired were large balks of timber, on which dust had plentifully collected. The shock caused by the explosion would throw the dust into the air, and the flame would set fire to it. Thus initiated the flame would extend through all the roads on which there was an uninterrupted supply of coal dust to support it.

The second part of this Address relates to inorganic, or mineral dust. When on the Peak of Tenerife in 1878, engaged in a pursuit mostly of a physiological kind, I had occasion to use a very delicate chemical balance. My object was to determine the amount of aqueous vapour given out of the lungs while in the shallow crater at the summit of the Peak, 12,200 feet above the sea. The heat was intense, as the sun shed its nearly vertical rays at mid-day on the fine white volcanic sand spread over the floor of the crater. At various places rocks projected, covered here and there with crystals of sulphur, and so hot that the hand could scarcely bear contact with them. Anticipating some difficulty in the use of the balance from the action of the wind, I had brought up with me a hamper and a blanket. After placing the hamper sideways, with the lid off, I proceeded, though not without some little trouble, to dispose the balance satisfactorily inside the basket; then, having thrown the blanket over the hamper, I stretched out at full length on the burning sand, nestling under the blanket, much as a photographer would cover himself and camera with a dark cloth. On trying to use the balance, it refused to act; its beam would not oscillate. A careful examination showed the instrument to be apparently in perfect order, when it occurred to me to wipe the knife edges at the points of suspension of the beam and pans. The balance then worked quite well, though, but for a few minutes only, again most provokingly declining to

oscillate ; indeed, it was only by constant wiping of the knife edges that I succeeded with my experiment. The cause of my trouble was clearly the presence of very fine mineral dust in the air, of which my senses were utterly unconscious. Hence it is that extremely fine particles of mineral dust may exist in the atmosphere, escaping detection by our senses, and such an occurrence is probably more frequent than is generally thought.

Professor Piazzzi Smyth, while on the Peak of Tenerife, witnessed strata of dust rising to a height of nearly a mile, reaching out to the horizon in every direction, and so dense as frequently to hide neighbouring hills. The Report of the Krakatoa Committee of the Royal Society contains the following interesting account, p. 421 (Mr. Archibald's contribution to the report):—In 1881 Professor S. P. Langley ascended Mount Whitney, in Southern California, with an expedition from the Alleghany Observatory ; at an altitude of 15,000 feet his view extended over one of the most barren regions in the world. Immediately at the foot of the mountain was the *Inyo Desert*, and in the east a range of mountains parallel to the Sierra Nevadas, but only about 10,000 feet in height. From the valley the atmosphere had appeared beautifully clear ; but, as stated in Professor Langley's own words, "from this aerial height we looked down upon what seemed a kind of level dust ocean, invisible from below, but whose depth was six or seven thousand feet, as the upper portion only of the opposite mountain range rose clearly out of it. The colour of the light reflected to us from this dust ocean was clearly red, and it stretched in every direction as far as the eye could reach, although there was no special wind or local cause for it. It was evidently like the dust seen in mid-ocean from the Peak of Tenerife—something present all the time, and a permanent ingredient of the earthy atmosphere."

Dust Storms.—These storms, as suggested by Dr. Henry Cook, (from whose paper to the *Quarterly Journal of the Royal Meteorological Society* in 1880, I am now quoting,) may be considered under three heads, according to their intensity—atmospheric dust, dust columns, and dust storms. Dr. Cook, alluding to occurrences in India, observes that there are some days on which, however hard and violently the wind may blow, little or no dust accompanies it ; while on others every little puff of air or current of wind forms or carries with it clouds of dust. If the wind which raises the dust is strong, nothing will be visible at the distance of a few yards, the sun at noon being obscured. The dust penetrates everywhere, and cannot be excluded from houses, boxes, or even watches, however carefully closed. The individual particles of sand appear to be in such an electrical condition that they are ever ready to repel each other, and are consequently disturbed from their position and carried up into the air.

Dust columns are considered by Dr. Cook as due to electrical causes. On calm, quiet days, when hardly a breath of air is stirring, and the sun pours down its heated rays with full force, little eddies arise in the atmosphere near the surface of the ground. These increase in force and diameter, catching up and whirling round bits of sticks, grass, dust, and lastly sand, until a column is formed of great height and considerable diameter, which usually,

after remaining stationary for some time, sweeps away across country at great speed. Ultimately it loses gradually the velocity of its circular movement and disappears. In the valley of Mingochar, which is only a few miles in width, and surrounded by high hills, Dr. Cook, on a day when not a breath of air stirred, counted upwards of twenty of these columns. They seldom changed their places, and when they did so moved but slowly across the level track. They never interfered with each other, and appeared to have an entirely independent existence.

Dr. Cook describes as follows a dust storm which took place at Jacobabad :—"The weather had been hot and oppressive, with little or no breeze, and a tendency for dust to accumulate in the atmosphere. On the evening of the storm heavy clouds gathered and covered the sky. About 9 p.m. the sky had cleared somewhat, and the moon shone. A breeze sprang up from the west, which increased and bore along with it light clouds of sand. About 9.30 p.m. the storm commenced in all its fury. Vast bodies of sand were drifted violently along. The stars and moon were totally obscured. It became pitch dark, and it was impossible to see the hand held close to the face. The wind blew furiously in gusts, and heaped the sand on the windward side of obstacles in its course. Lightning and thunder accompanied it, and were succeeded by heavy rain. The storm lasted about an hour, when the dust gradually subsided. The sky again became clear, and the moon shone brightly. The storm appeared to have entirely relieved the electrical condition of the atmosphere. A pleasant freshness followed, and the oppressive sensation before mentioned was no longer experienced. This, indeed, is the general effect of storms in Upper Scinde. The air is cooled, the atmosphere cleared, and the dusty condition of the atmosphere which usually precedes them for several days completely disappears."

In the case of a memorable sand-storm which occurred at Aden on July 16th, 1878, and recorded by Lieut. Herbert Russell, there was a remarkable play of light on the objects which remained within sight. The sudden darkness from the storm gave a peculiar and ghastly tint to the white sand and neighbouring plain, while the curling masses of sand drifted before the gale, resembling a dark yellow smoke. The varied lights, quickly changing, were curious and most grand; the sea a clear green, and Slave Island and Shum-Shum, usually of an arid brown colour, became of an ashy white.

In a dust storm I experienced myself at Luxor, on the Nile, the suffocating effect of the sand as it drove into the lungs and air passages was very trying. People rushed to the adjacent river-side, where some relief was found.

A book on *Whirlwinds and Dust Storms in India*, by P. L. H. Baddeley, Surgeon Bengal Army, 1860, gives some interesting information on the electrical character of dust storms and dust pillars. When at Lahore in 1847, this gentleman was desirous of experimenting on the electrical state of the atmosphere in a dust storm, and with this object he projected into the air, on the top of his house, an insulated copper wire fixed to a bamboo, the wire was brought through the roof into his room, and connected with a gold-leaf

electrometer, a detached wire communicating with the earth. A day or two after, during the passage of a small dust storm, he observed the passage of vivid sparks from one wire to the other, of course, strongly affecting the electrometer. He subsequently witnessed at least sixty dust storms of various sizes, all presenting the same kind of phenomena.

Volcanic Dust.—This dust consists mainly of powdered vitrified substances, produced by the action of intense heat. It is interesting in many respects. The so-called ashes or scorix shot out in a volcanic eruption are mostly pounded pumice, but they also originate from stones and fragments of rocks which, striking against each other, are reduced into powder or dust. Volcanic dust has a whitish-grey colour, and is sometimes nearly quite white. Thus it is that, in summer, the terminal cone of the Peak of Tenerife appears from a distance as if covered with snow; but at that season of the year there is no snow on the mountain; the white cap on the Peak is entirely due to pumice ejected centuries ago. It is probably to this circumstance that the island and Peak owe their name, as in the Guanche language the words *Tener Ifa* mean *white mountain*.

The friction caused by volcanic stones and rocks as they are crushed in their collision develops a mass of electricity, which shows itself in brilliant displays of branch lightning darting from the edges of the dense ascending column. During the great eruption of Vesuvius, in 1822, they were continually visible, and added much to the grandeur of the spectacle. It not infrequently happens that dust emitted from Vesuvius falls into the streets of Naples; but this is nothing in comparison with the mass of finely-powdered material which covered and buried the towns of Pompeii, Herculaneum, and Stabix in the year 79 A.D.

On this occasion, according to the younger Pliny, total darkness from the clouds of volcanic ashes continued for three days, during which time ashes fell like a mantle of snow all over the surrounding country. When the darkness cleared away the calamity was revealed in all its awful extent, the three towns having disappeared under the showers of dust.

The eruption of Krakatoa, a mountain situated on an island in the Straits of Sunda, exceeded, in all probability, in its deadly effects, and as a wonderful phenomenon of nature, the outburst of Vesuvius in the year 79. The Krakatoa Committee of the Royal Society have collected and published in their interesting Report particulars of that memorable eruption, all of them thoroughly authenticated and reliable. The following is extracted from a communication to the report by Professor Judd:—On the 26th August, 1883, it was evident that the long continued moderate eruptions of Krakatoa had passed into the paroxysmal stage. That day, about 1 p.m., the detonations caused by the explosive action attained such a violence as to be heard at Batavia and Buitenzorg, about 100 English miles away. At 2 p.m. Captain Thompson, of the *Medea*, then sailing at a point 76 miles ENE of Krakatoa, saw a black mass like smoke in clouds rising to an altitude which has been estimated at no less than seventeen miles (nearly six times the height of Mont Blanc).

If this surmise be correct, some idea of the violence of the outburst can be formed from the fact that during the eruption of Vesuvius in 1872 the column of steam and dust was propelled to a height of from 4 to 5 miles only.

At 8 p.m. the explosions were loud enough to be heard 150 miles away. At Batavia and Buitenzorg the noise is described as being like the discharge of artillery close at hand. Windows rattled, pictures shook, but there was nothing of the nature of earthquake shocks—only strong air vibrations.

Captain Woolridge, of the *Sir R. Sale*, viewing the volcano at sunset on the 26th, describes the sky as presenting a 'most terrible appearance, the dense mass of cloud of a murky tinge being rent with fierce flashes of lightning. At 7 p.m., when from the vapour and dust clouds intense darkness prevailed, the whole scene was lighted up by electrical discharges, and at one time the cloud above the mountain presented the appearance of an immense pine tree, with the stem and branches formed of volcanic lightning. The air was loaded with excessively fine ashes, and there was a strong sulphurous smell. The steamer *G. G. Loudon*, within 20 or 30 miles of the eruption, passed through a rain of ashes and small bits of stone.

Captain Watson, of the ship *Charles Bal*, at a spot about a dozen miles off the island, records the phenomena of chains of fire appearing to ascend between the volcano and the sky, while on the south side there seemed to be a "continual roll of balls of white fire." These appearances were doubtless caused by the discharge of white-hot fragments of lava rolling down the sides of the mountain. From midnight till 4 a.m. explosions continually took place, the sky one second being intense blackness, the next a blaze of fire.

All the eye-witnesses agree as to the splendour of the electrical phenomena. Captain Woolridge, viewing the eruption from a distance of 40 miles, speaks of the great vapour cloud resembling an immense wall, with outbursts of fork lightning, like large luminous serpents rushing through the air. After sunset, this dark wall assumed the appearance of a blood-red curtain, with the edges of all shades of yellow—the whole of a murky tinge, and attended with fierce flashes of lightning. It was reported from the *G. G. Loudon* that lightning struck the mast-head conductor five or six times, and that the mud-rain which covered the masts, rigging, and decks was phosphorescent. The rigging presented the appearance of St. Elmo's fire, which the native sailors were busily engaged putting out with their hands, alleging that, if any portion found their way below, a hole would burst in the ship; not that they feared the ship taking fire, but they thought that the light was the work of evil spirits, and that if it penetrated to the hold the evil spirits would triumph in their design to scuttle the ship.

By these grand explosive outbursts the old crater of Krakatoa was completely eviscerated, and a cavity formed more than 1,000 feet in depth; while the solid materials thrown out from the crater were spread over the flanks of the volcano, forming considerable alterations in their forms.

The sea disturbance which accompanied the eruption of Krakatoa was carefully investigated by Captain Wharton, Hydrographer to the Admiralty :

—"The rush of the great sea wave over the land, caused by the violent abrasion in the crater, aided by the action on the water of enormous masses of fallen material, caused great destruction of life and property in the Straits of Sunda. By the inrush of these waves on land all vessels near the shore were stranded, the towns and villages near the coast devastated, two of the lighthouses were swept away, and the lives of 86,880 of the inhabitants sacrificed. It was estimated that the wave was about 50 feet in height when it broke on the shore."

On the morning of the 27th, between 10 and 11 a.m., three vessels at the eastern entrance of the Straits encountered the fall of mingled dust and water, which soon darkened the air, and covered their decks and sails with a thick coating of mud. Some of the pieces of pumice falling on the *Sir R. Sale* were said to have been of the size of a pumpkin. All day on the 27th the three vessels were beating about in darkness, pumice-dust falling upon them in such quantities as to employ the crew for hours in shovelling it from the decks and in beating it from the sails and rigging. At Batavia, 100 miles from Krakatoa, the sky was clear at 7 a.m., but at 11 a.m. there fell a regular dust-rain; at 11.20 complete darkness pervaded the city. The rain of dust continued till 1, and afterwards less heavily till 8 p.m.

The speed and distance attained by the pumice ejected from the volcano may be conceived from the fact stated in Mr. Archibald's contribution to the Report, that dust fell on the 8th of September more than 8,700 English miles from the seat of the eruption.

The great mass of the pumice thrown out during the eruption presented a dirty greyish-white tint, being very irregular in size. It was undoubtedly due to the collision of fragments of pumice as they were violently ejected from the crater; the noise they produced was even more striking than the sound of the explosion.

The dust ejected from Krakatoa did not all fall back at the same time upon the sea and earth; as the lightest portions of it formed haze, which was propagated mostly westwards. Mr. Archibald states in the Report that most observers agree in considering this haze as the proximate cause of the twilight glows, coloured suns and large coronæ, which were seen for a considerable time after the eruption. The haze was densest in the Indian Ocean and along the equatorial belt, and was often thick enough to hide the sun entirely when within a few degrees from the horizon.

And now, ladies and gentlemen, I must bring this Address to a conclusion, and thank you for having followed me over a long, dusty track. I hope I have succeeded in showing that infinitely small objects, no larger than particles of dust, act important parts in the physical phenomena of nature, just as small and apparently unimportant events occasionally lead to others of the greatest magnitude.

REPORT OF THE COUNCIL

FOR THE YEAR 1889.

THE Council have much pleasure in congratulating the Fellows on the generally prosperous state of the Society; the past year's work, though not in any respect exceptional, having been thoroughly successful. The total number of Fellows is 549, being an increase of 24 on the previous year; the finances are improving and the Library is overflowing. The routine of reducing and publishing the observations made at the Society's stations, and preparing and supervising the reports and papers read at the meetings, take much time, and in carrying on the work the Council have received considerable help from the various Committees, as well as from the members of the staff. The Committees and the Members thereof are as follows, viz. :—

GENERAL PURPOSES COMMITTEE.—The President, Secretaries, Foreign Secretary, Treasurer, Messrs. Bayard, Brewin, Ellis, Latham, and Williams.

EDITING COMMITTEE.—Messrs. Blanford, Inwards, and Scott.

STANDING REFEREE ON PAPERS.—Mr. Ellis.

ANNUAL EXHIBITION COMMITTEE.—The President, Secretaries, Messrs. Ellis, Scott, Strachan, and Whipple.

DECREASE IN WATER SUPPLY COMMITTEE.—The President, Messrs. Chatterton, Latham, and Symons; with Mr. Scott, representing the Meteorological Council.

WIND FORCE COMMITTEE.—The President, Secretaries, Messrs. Archibald, Chatterton, Dines, C. Harding, Laughton, Munro, Scott, and Toyabee; with Mr. Whipple, representing the Kew Committee.

THUNDERSTORM COMMITTEE.—The President, Secretaries, Messrs. Abercromby, Beaufort, Inwards, Scott, and Whipple.

LIBRARY CATALOGUE COMMITTEE.—Messrs. Eaton, Scott, and Symons.

The *Annual Exhibition of Instruments*, which was held on March 19th to 22nd, was attended by a large number of Fellows and visitors, and gave much satisfaction. It was held as usual in the rooms of the Institution of Civil Engineers, and the Catalogue contained a description of 71 different exhibits, arranged under the following divisions—1. Aetionometers; 2. Solar Radiation Thermometers; 3. Sunshine Recorders; 4. New Instruments made since the last Exhibition; 5. Models; and 6. Photographs, Drawings, &c. The Council recommend to the Fellows the perusal of the catalogues of this and the previous Exhibitions, as containing valuable information in a condensed form.

The *Wind Force Committee* have had several meetings, and have also visited Hersham in Surrey, to witness the experiments made by Mr. Dines, with the assistance of Mr. Whipple and Mr. Munro. Reports were read at the meetings held in May and December and are printed in the *Quarterly Journal*. The experiments, as far as they have gone, are of considerable value, showing that the factor (8) of the Robinson's Anemometer (Kew pattern) is decidedly too high, also that no simple factor is of general applica-

bility. The best thanks of the Society are due to Mr. Dines for the great skill he has displayed in the inquiry, and the trouble and large amount of time he has devoted to the subject.

Thunderstorm Observations and Discussions.—In the early part of the year an extra assistant was engaged to tabulate the large mass of materials which the Society has collected respecting thunderstorms. Under Mr. Marriott's supervision he extracted all the reported dates of thunderstorms in England and Wales during the 17 years 1871-1887. The results were embodied in a paper, which was read at a meeting of the Society and printed in the *Journal*. This paper is to be followed by a careful discussion of the phenomena recorded during the thunderstorms of 1888-89, which, it is hoped, will soon be ready for reading at a meeting of the Society. Several new photographs of lightning flashes have been received during the year.

The Inquiry respecting the Helm Wind has for the present been discontinued, partly owing to the difficulty in getting the observers together before the phenomena have disappeared, and partly because there have been of late so few Helm Winds. Mr. Marriott read a paper as a Report on the subject, illustrated by a map and diagrams, which has been printed in the *Journal*. The Committee are of opinion that in some of the early accounts the intensity of the wind force was exaggerated.

Inspection of Stations.—The inspection this year comprised the stations in the South-west of England and in Wales, which were all found in a satisfactory condition. The alterations in the zero points of the thermometers were, however, more numerous than usual. The particulars will be found in Mr. Marriott's Report, Appendix II. (p. 98).

Jordan Sunshine Recorder.—As several of the Fellows and observers who use the Jordan Photographic Sunshine Recorder have measured the trace before fixing, while others have fixed the trace first, the Council have requested the observers who use this instrument always to fix the trace before measuring. By this means uniformity will be secured.

International Congress of Hygiene.—At the request of Sir Spencer Wells and other members of the Committee for organising the International Congress of Hygiene and Statistics to be held in London in 1891, the Council appointed Dr. Marcet and Dr. Tripe as delegates to represent the Society on the General Committee.

Returns supplied to the Meteorological Council.—For many years past the Society has supplied the Meteorological Council with copies of returns from a number of stations. Some slight modifications in the arrangement have recently been made, but they do not materially affect the amount of work, or the payment made to the Society by the Meteorological Office.

Quarterly Journal and Meteorological Record.—These publications have been continued as usual, and the former contains many interesting Addresses, Reports, and Papers. The *Record* has appeared with greater regularity, as the working staff has to a certain extent recovered from the difficulty arising in 1887 from the nearly simultaneous resignation of two of the computers who had been several years in the service of the Society, and fully under-

stood their work. Few changes have occurred in the stations. The observations from Cromer, Portsmouth, and Torquay have been discontinued; whilst those from St. Michael's Priory, near Hereford (Second Order Station), and from Aberystwith (Climatological), have been added to the list printed in the *Record*.

The *Meetings* of the Society have been well attended, and have been held as usual in the rooms of the Institution of Civil Engineers, by permission of the President and Council of that body, who have thus greatly contributed to the usefulness of this Society, inasmuch as, independently of the pecuniary saving, such commodious and central rooms could not otherwise have been obtained.

The *Catalogue* of the Library having been published in 1876, and a very large number of books having since been added to the Library, the Council took into their consideration the preparation of a new Catalogue. They decided that, instead of a supplement to the previous one, a complete Catalogue should be compiled, and that this should be arranged alphabetically, under authors' names. The Catalogue Committee consider that they have been fortunate in obtaining the services of Mr. J. S. Harding, F.R.Met.Soc., as Editor; and they believe that the volume will be distributed to the Fellows in 1890, and will be alike creditable to the Society and useful to all Meteorologists. The cost, which will probably be between £100 and £150, is already provided for.

The surplus stock of the *Society's Publications* having largely increased beyond the convenience of storage, it was decided to distribute the surplus copies of the publications dated before 1880 amongst the Fellows, after reserving 25 copies of each for stock. A notice was accordingly issued to the Fellows, and a large number of the surplus copies have been accordingly sent out.

Owing to the increase of the Library, the *shelf accommodation* has become insufficient, and no additional space being available in the Society's rooms, application was made to Mr. Barnes, from whom those now occupied are rented, and he has kindly placed several shelves at their disposal, where a large number of non-meteorological serials can be placed and obtained when required for reference. This offer has been accepted with thanks. The rooms occupied by the Society have been whitewashed, painted and repaired, and other improvements made in the accommodation, but this is insufficient for our wants. A Committee has been therefore appointed to make inquiries in the neighbourhood, but the rent asked for suitable rooms was too high. In these circumstances the Council have initiated a New Premises Fund, by investing the sum of £50 as a commencement towards the amount necessary to provide better accommodation. The Council hope that many of the Fellows will assist in carrying out this scheme.

It is to be remembered that owing to the comparative youthfulness of our Society we are in a worse position than many of the other Societies, *e.g.* all the following have rooms free of all charge, and of rates and taxes provided by Government, *viz.*—

The Royal	The Geological
The Society of Antiquaries	The Linnæan
The Royal Astronomical	The Chemical

and though the Royal Geographical Society is not provided with rooms, it receives a Parliamentary grant of £500 per annum "to enable the Society to provide suitable rooms in which to hold their meetings, and to exhibit to the public, free of charge, their collection of maps."

Fellows.—The changes in the number of Fellows during the year are shown in the following Table:—

Fellows.	Annual.	Life.	Honorary.	Total.
1888, December 31 ...	875	182	18	525
Since elected	+ 68	+ 4	...	+ 67
Since compounded	— 1	+ 1	...	0
Deceased	— 9	— 6	— 1	— 16
Retired	— 19	...	...	— 19
Defaulters	— 8	...	...	— 8
1889, December 31 ...	401	181	17	549

Deaths.—The Council have to announce with much regret the deaths of Sixteen Fellows, including one Honorary Member, Prof. Elias Loomis. The names are:—

Rt. Hon. Edward Pleydell Bouverie, M.A., F.R.S.	elected June 15, 1864.
George Daniel Brumham	„ Feb. 17, 1869.
William Brown Clegram, M.Inst.C.E.	„ Mar. 15, 1876.
Warren de la Rue, M.A., D.C.L., Ph.D., F.R.S.	„ Apr. 17, 1867.
John George Gamble, M.A., M.Inst.C.E.	„ Feb. 18, 1880.
Henry Hudson, M.D.	„ Nov. 17, 1869.
Major Charles Henry Maurice Kensington, R.E.	„ Mar. 16, 1887.
Hugo Leupold, Assoc.M.Inst.C.E.	„ Mar. 19, 1884.
Major Edward Windus Mathew, D.L., J.P.	„ June 15, 1881.
James Muir, M.Inst.C.E.	„ May 15, 1878.
William Parkes, M.Inst.C.E.	„ June 15, 1864.
Rev. Stephen Joseph Perry, S.J., M.A., F.R.S.	„ Apr. 21, 1869.
James Simpson, M.Inst.C.E.	„ Apr. 20, 1870.
George William Stevenson, M.Inst.C.E., F.G.S.	„ Feb. 15, 1882.
Alfred Hope Wood, Assoc.M.Inst.C.E.,	„ June 15, 1881.

APPEN.

STATEMENT OF RECEIPTS AND PAYMENTS

RECEIPTS.		£	s.	d.	£	s.	d.
Balance from 1888.....					342	4	2
Subscriptions for 1889		607	16	0			
Do, former years		45	2	0			
Do, paid in advance.....		59	1	0			
Life Compositions.....		105	0	0			
Entrance Fees		48	0	0			
		<hr/>			864	19	0
Meteorological Office—Copies of Returns		99	2	11			
Do. Grant towards Inspection Expenses		25	0	0			
		<hr/>			124	2	11
Dividends on Stock					61	12	2
Sale of Publications.....					39	1	0
Repaid by Authors for Corrections					2	7	0
Grant for Thunderstorm Inquiry					30	8	6

£1464 14 9

DIX I.

FOR THE YEAR ENDING DECEMBER 31ST, 1889.

PAYMENTS.

	£	s.	d.	£	s.	d.
<i>Journal, &c. :—</i>						
Printing Nos. 69 to 72	140	1	0			
Illustrations	21	17	1			
Authors' Copies	14	10	0			
Meteorological Record, Nos. 31 to 34.....	48	9	6			
Registrar-General's Reports	8	8	0			
				238	5	7
<i>Printing, &c. :—</i>						
General Printing	32	2	0			
Forms, &c.	8	10	6			
Stationery	19	8	8			
Books and Bookbinding	27	6	10			
Revision of Library Catalogue MS.	10	0	0			
				97	8	0
<i>Office Expenses, &c. :—</i>						
Salaries	327	8	0			
Rent and Housekeeper	48	9	0			
Repairs, Coals, &c.	13	10	0			
Postage, &c.	58	3	0			
Petty Expenses	12	17	7			
Befreshments at Meetings	13	13	7			
Exhibition of Instruments.....	5	13	6			
				479	14	7
<i>Observations :—</i>						
Inspection of Stations	40	18	11			
Observers at Old Street and Seathwaite.....	7	2	0			
Instruments	1	3	4			
Wind Force Experiments	2	13	6			
Thunderstorm Discussion	22	0	0			
				73	17	9
<i>Stock :—</i>						
Purchase of £100 N. S. W. 4 per cent. Inscribed Stock ..	114	3	0			
Do. £51 5s. 8d. Consols (New Premises Fund) ..	50	0	0			
				164	3	0
				1048	8	11
<i>Balance :—</i>						
At Bank of England	399	10	10			
In hands of Assistant-Secretary	16	15	0			
				416	5	10
				£1464	14	9

Examined and compared with the Vouchers, and found correct,

J. S. HARDING,	} Auditors.
H. SOWERBY WALLIS,	

January 9th, 1890.

APPENDIX I.—Continued.
ASSETS AND LIABILITIES ON JANUARY 1st, 1890.

LIABILITIES.		ASSETS.	
	£ s. d.		£ s. d.
To Subscriptions paid in advance	59 1 0	By Investment in M. S. & L. R. 4½ Debenture Stock, £800 at 141	1128 0 0
" Grant for Thunderstorm Inquiry unexpended	8 8 6	" Investment in N. S. W. Stock, 4 per Cent. Inscribed, £800 at 114	684 0 0
" Excess ¹ of Assets over Liabilities	67 9 6	" Investment in 2½ per Cent. Consols, £250 at 97½	243 2 5
	2648 1 4	" Do. £51 5s. 8d. (New Premises Fund)	49 17 6
			2105 0 0
		" Subscriptions unpaid, estimated at	40 0 0
		" Entrance Fees unpaid	23 0 0
		" Interest on Stock	81 5 0
			94 5 0
		" Furniture, Fittings, &c.	30 0 0
		" Instruments	70 0 0
			100 0 0
		" Cash in hands of Bank of England	399 10 10
		Do. the Assistant-Secretary	16 15 0
			416 5 10
			<hr/>
			£2715 10 10
			<hr/>

¹ This excess is exclusive of the value of the Library and Stock of Publications.

J. S. HARDING, }
H. SOWERBY WALLIS, } *Auditors.*
WILLIAM MARRIOTT, *Assistant-Secretary.*

January 9th, 1890.

APPENDIX II.

REPORT ON THE INSPECTION OF THE STATIONS, 1889.

All the stations in Wales and the South-west of England have been visited this season, and were found to be in a satisfactory condition.

The alterations in the zeros of the thermometers were more numerous than I have found in any previous inspection. This is, no doubt, largely due to the fact that three years have elapsed since the last inspection. The following is a summary of the changes in the zeros of the thermometers :—

Dry.	Wet.	Max.	Min.	Earth.
5 risen 0·1	6 risen 0·1	2 risen 0·1	1 risen 0·2	1 risen 0·2
7 „ 0·2	5 „ 0·2	2 „ 0·2	1 „ 0·1	1 „ 0·8
8 „ 0·8	2 „ 0·8	1 „ 0·8	1 gone down 0·1	2 „ 0·4
			4 „ 0·2	
			1 „ 0·8	
			1 „ 0·4	
			1 „ 0·7	
			1 „ 2·2 ¹	

At two stations Negretti and Zambra's pattern of earth-thermometer is in use. In this instrument the thermometer is enclosed in a thick glass tube, with the bulb and a portion of the stem also embedded in wax. The thermometer is consequently exceedingly sluggish; so much so that I was quite unable to compare it with my standard thermometers.

In three instances the thread of mercury forming the index in Phillips's maximum thermometer had become so long that there was a risk of the air bubble working into the bulb and throwing the instrument out of order. These indices I shortened considerably by placing the bulb in a mixture of salt and ice, which reduced the temperature nearly to zero.

When in Wales I called upon Dr. Rees Davies, the Medical Officer of Health at Aberystwith, and asked him if he would observe for the Society. This he has agreed to do. The instruments belong to the Corporation of Aberystwith, and are mounted in the enclosure selected by Mr. Symons in 1875. A Jordan sunshine recorder has recently been obtained. We may now expect some valuable observations from that part of Wales.

WILLIAM MARRIOTT.

October 15th, 1889.

NOTES ON THE STATIONS.

ABERYSTWITH, *July 22nd.*—I called upon Dr. D. Rees Davies, the Medical Officer of Health, and found that he was willing to furnish the Society with observations. The instruments are in the same position as

¹ This was a grass minimum. The change was not due to the condensation of spirit at the top of the tube.

described in Vol. III. p. 53. On comparing the thermometers I found that the zeros of the dry and wet had risen $0^{\circ}8$, the maximum $0^{\circ}1$, and the minimum decreased $0^{\circ}4$. A Jordan sunshine recorder has recently been added to the station.

ASHBURTON, *September 4th*.—The rain-gauge had been moved about 12 feet south of its former position about two months previous to my visit. The thermometer screen required to be painted and made firmer. The zeros of the maximum and dry bulb thermometers had risen $0^{\circ}2$, and the minimum had decreased $0^{\circ}2$.

BABBACOMBE, *August 28th*.—The station was in good order. Some slight changes had taken place in the zeros of most of the thermometers since the last inspection in 1886. The grass minimum thermometer had however been broken, and the zero of another one, which was being used in its place, was found to have decreased $2^{\circ}2$ in the past year.

BRAMPFORD SPEKE, *August 26th*.—The instruments were in the same position as at the last inspection. The thermometer screen required painting. The zeros of the dry and wet bulb thermometers had risen $0^{\circ}8$.

BUDE, *September 3rd*.—There was no change in the thermometers. Mr. Arthur contemplates discontinuing the observations at the end of 1890.

BURGHILL, *July 18th*.—As trees had grown up very much in the neighbourhood of the thermometer screen, I recommended that it be moved to a more open situation. The screen also required painting. As the shrubs round the rain-gauges had also grown very much Dr. Chapman was requested to move one of the gauges further to the north.

BUXTON, *July 25th*.—The observations have been in charge of Mr. W. H. Beck since February. The thermometers were all correct. The column of mercury in the maximum however was very long, and was liable to get out of order. The Jordan sunshine recorder was not firmly fixed, and required adjustment.

CARMARTHEN, *August 23rd*.—Dr. Hearder was away at the time of my visit, but the deputy observer showed me the instruments. The thermometers were all correct except the wet bulb, which had gone up $0^{\circ}2$.

CHELTENHAM, *July 17th*.—The thermometers required re-arranging in the screen. The zeros of the mercurial thermometers had risen: the dry $0^{\circ}2$, wet $0^{\circ}1$, maximum $0^{\circ}8$.

CHURCHSTOKE, *July 20th*.—The thermometer screen, which was fixed on one stout post, was rather shaky. I recommended that it be fixed on four posts. The thermometers were all correct. The sunshine recorder is placed on the tower of Mellington Hall, and has a very open exposure.

CULLOMPTON, *August 26th*.—This station was in good order. The thermometers were correct except the wet bulb, which had gone up $0^{\circ}2$. The earth thermometer is now not used. The sunshine recorder is mounted on an iron plate fixed on the top of a lamp post, which is built into a brick pier. The exposure is very good; the glass shade which formerly covered the recorder has been removed.

EXETER, *August 27th*.—I called at the Hospital and found that no

observations had been made since the Rev. P. H. Newnham's death. Dr. R. Coombe, the House Surgeon, agreed to take the observations for a month as an experiment, and then if satisfactory, to continue them. The thermometer screen required painting.

FALMOUTH, August 31st.—The station was in good order. The zeros of the dry and wet bulb thermometers had gone up $0^{\circ}1$.

GWERNYFED PARK, July 19th.—This station is close to Three Cocks Junction, Brecknockshire, 5 miles South-west of Hay, and 8 miles North-west of the Black mountains. The situation and exposure are very open. Since my visit the station has been equipped so as to fulfil the requirements of the Society.

ILFRACOMBE, August 24th.—The funnel of the rain-gauge had become corroded and required attention. A new funnel with deeper rim was subsequently ordered, and put in position on January 1st, 1890. The zero of the dry-bulb thermometer had risen $0^{\circ}2$.

LLANDUDNO, July 24th.—The exposure of the instruments was much better than at the previous inspection; the shrubs, &c. having been cleared away, and a plot of grass laid down. The minimum thermometer had $0^{\circ}3$ of spirit at the top of the tube. The sunshine recorder is mounted on the roof of the Old Telegraph Station on the top of the Great Orme's Head, where the exposure is very good. The recorder, however, was not in good adjustment.

MARLBOROUGH, July 16th.—The muslin on the wet-bulb thermometer required changing. The zero of the dry-bulb thermometer had gone up $0^{\circ}3$. The grass minimum thermometer had some spirit at the top of the tube. The earth thermometers, which are enclosed in a thick outer tube, and have the bulb surrounded by wax, are so sluggish that it was impossible to test them. As Mr. Storey had left the College, the instruments were again under the charge of Mr. Hewitt.

OAKMOOR, July 24th.—The maximum was inclined with the bulb slightly upwards, so that the thermometer had to be gently tilted before it could be read. I altered the position of the maximum and minimum, so that, no doubt, better results will now be obtained. The thermometer screen required painting.

PRINCETOWN, August 30th.—The zeros of the dry and wet bulb thermometers had risen $0^{\circ}1$. The thermometer screen required painting. The observations in the morning are taken by Mr. Hamick, a warder, and in the evening by Dr. Stone, who always reads the barometer. It appears that the officials of the prison open the door of the thermometer screen occasionally during the day, and look at the thermometers.

ROSS, July 17th.—The thermometer screen and rain-gauge were better exposed than at the previous inspection, as a number of shrubs had been cut down. The screen had also been mounted on four posts. The muslin on the wet bulb required changing.

ROUSDON, September 5th.—On comparing the thermometers it was found that the 1 ft. and 4 ft. earth thermometers had risen $0^{\circ}4$, and the 2 ft. $0^{\circ}8$,

while the minimum thermometer had gone down $0^{\circ}2$. As the present site, which is in a kitchen garden, is somewhat sheltered, Mr. Peek proposes removing the instruments to a more open situation near the Astronomical Observatory on January 1st, 1890. Simultaneous readings will be taken at both sites during the next three months. In addition to the ordinary instruments Mr. Peek has also a large cup anemograph (on the Water Tower), a Gordon electrical anemometer, a Richard barograph, and 8 evaporation tanks.

SIDMOUTH, *August 27th*.—The station was in good order. The zero of the dry bulb thermometer had gone up $0^{\circ}2$, and the wet $0^{\circ}1$.

ST. MICHAEL'S PRIORY, *July 18th*.—I called here and selected sites for the instruments which Canon Howlett proposes putting up. The exposure is very good. St. Michael's Priory is $2\frac{1}{2}$ miles South-west of Hereford. It is anticipated that the observations will be continuous during the vacations, as there are always some Professors in residence.

STOWELL, *August 21st*.—This station was in good order. The zeros of the dry and wet bulb thermometers had gone up $0^{\circ}2$, and the minimum had gone down $0^{\circ}8$. The earth thermometer was so sluggish that it could not be tested. In addition to the usual instruments the Rev. H. J. Poole has a Jordan sunshine recorder, a Richard barograph and thermograph, and a percolation gauge.

TEIGNMOUTH, *August 29th*.—The instruments are in the same position as at the last inspection. The screen had recently been fixed on new posts and painted. The minimum thermometer had gone up $0^{\circ}2$.

TORQUAY, *August 28th*.—Mr. Chandler has a set of instruments in the grounds of the Devon Rosary, which are well exposed except on the east. The Jordan sunshine recorder is mounted on a stone pier on the top of Chapel Hill, near Torre Railway Station. The exposure is very good.

WESTON-SUPER-MARE, *August 22nd*.—The instruments were in the same position as at the previous inspection. The dry and wet bulb thermometers had gone up $0^{\circ}2$. The screen required painting.

APPENDIX III.

OBITUARY NOTICES.

THE RIGHT HON. EDWARD PLEYDELL BOUVERIE was born in 1818, and was the second son of the third Earl of Radnor. He was educated at Harrow and at Trinity College, Cambridge, where he graduated M.A. in 1838. He entered public life very soon after leaving the University. From January to June 1840 he was *précis* writer to Lord Palmerston.

He was called to the Bar at the Inner Temple in 1843, and in the following year he was returned to Parliament in the Liberal interest as Member for Kilmarnock, which constituency he continued to represent until 1874, when

he was an unsuccessful candidate. During his 80 years of Parliamentary life Mr. Bouverie was a prominent figure in the House of Commons. From July 1850 to March 1852 he was Under-Secretary of State for the Home Department, and from April 1853 to March 1855 he was Chairman of Committees. In March 1855 he was made Vice-President of the Board of Trade, and in August of the same year he vacated this office and became President of the Poor Law Board, which position he held until 1858. In 1857 he was appointed one of the Committee of Council of Education. He was Second Church Estates Commissioner from August 1859 until November 1865, and from the year 1869 he was one of the Ecclesiastical Commissioners for England.

Mr. Bouverie was also a director of many great companies, among them being the Great Western Railway Company, and the Peninsular and Oriental Company.

Mr. Bouverie was at one time a prolific contributor to the correspondence columns of *The Times*, and his letters, which appeared over the signature "E. P. B.", more especially those on the subject of the Bulgarian atrocities in the autumn of 1876 and the following year, were widely read and widely commented on.

He died on December 16th, 1889.

Mr. Bouverie was elected a Fellow on June 15th, 1864.

GEORGE DANIEL BRUMHAM was born December 20th, 1827, at Sandy, in Bedfordshire, but removed to London at an early age. Entered first as a clerk, he subsequently became a member of the Stock Exchange, with which he was connected for a quarter of a century. He continued a member for some few years after retiring from active practice, but eventually devoted himself almost wholly to Meteorology. He was elected Fellow on February 17th, 1869, and contributed to the Society the following papers:—

"On some of the Laws which appear to regulate the Temperature of Months and Seasons." *Proceedings*, Vol. IV. p. 75.

"On some of the Laws which appear to regulate the Temperature of Summer months and Seasons." *Proceedings*, Vol. V. p. 129.

"On the Moon's influence in connection with extremes of Temperature." *Quarterly Journal*, Vol. III. p. 80.

He also wrote many articles and letters in the *Meteorological Magazine* upon the subject to which he devoted almost lifelong care and work, viz. the elaboration from the records of the past of rules indicative of the probable character of future seasons.

Mr. Brumham's health was never strong, and he was carried off by an attack of bronchitis on April 20th, 1889.

WILLIAM BROWN CLEGAM, whose death occurred on the 3rd of June 1889, was born on the 1st of October 1809 at Shoreham, Sussex, where his father, who began life as a sailor, had settled in order to take charge of improvement works designed by him for the harbour at that place. He was

brought up by his father to the profession of a civil engineer, and before he quitted Shoreham in 1827 had assisted him in his drawings and surveys. At this time Mr. Clegram, senior, was selected to take charge, under Mr. Telford, of the Gloucester and Berkeley ship-canal, then not yet completed. His son almost at once entered the same service, being appointed Clerk in 1829.

Whilst holding this office he had leisure to assist his father in designing new basins, quays, graving-docks and other works at Gloucester; and in 1861 he succeeded to the post of Engineer and Superintendent. At this time the important and practically untried system of towing by means of screw steam-tugs was introduced on this canal, and formed the subject of a Paper he presented to the Institution of Civil Engineers entitled "Results of the Employment of Steam-Power in Towing Vessels on the Gloucester and Berkeley Canal."¹

Mr. Clegram was always an ardent advocate for the retention and improvement of the water-ways of the country, and had more than once to sink personal feelings in their defence as well as to embark capital in their advancement.

In conjunction with the late Mr. T. E. Harrison, C.E., he carried out important improvements at the sea entrance to the canal at Sharpness, the position of which was the subject of long and mature deliberation, rendered none the easier by the consideration that it was necessary to provide access for vessels of some 8,000 tons displacement in a channel where the tide frequently set at the rate of 7 knots an hour. That these works proved equal to the requirements of the trade of the district for fifteen years is evidence of his sound judgment and power of acquiring technical knowledge from others; and that they can scarcely be said now to be on this footing is due to the fact that Mr. Clegram had to make the most of funds, provided in a great measure by his untiring activity, in a district not specially favoured with a redundant or too wealthy population. The works consisted of open wooden piers on either side of the entrance into a tidal basin, with lock, floating-basin, graving-dock, and connecting-cut to the old works. He was also one of the prime movers in the founding of the Severn Bridge.

Perhaps the chief noticeable features of his character were the wide range of his attainments, and the thoroughness with which he was wont to grasp every detail of the work he set himself to carry through. He was a good artist, a keen observer of nature, with both microscope and telescope, a great reader, and an accomplished musician. To all about him he was ever considerate and courteous, with a kind word for every one with whom he came in contact. His advice was at all times eagerly sought by his more intimate friends, and his judgment relied upon as sound and trustworthy. He was, like his father, a systematic recorder of daily events, small and great, which included meteorological observations.

He was elected a Fellow of this Society on March 15th, 1876.

¹ *Minutes of Proceedings Inst. C.E.*, Vol. XXVI. p. 1.

WARREN DE LA RUE was born at Guernsey on January 18th, 1815, and was the son of Mr. Thomas de la Rue, the founder of the eminent firm of manufacturing stationers in London. He was educated at the College Saint-Barbe in Paris, where he remained until he returned to London to enter his father's business. He subsequently succeeded his father as head of the firm, from which he retired in 1880.

In the course of his conduct of the firm Mr. de la Rue applied his scientific knowledge to purposes of practical utility and patented a number of inventions, among them being processes for utilising earth oils, and machinery for simplifying the making of writing materials.

The principal scientific work in which he distinguished himself was the application of photography to the recording of celestial phenomena. The photographs, when measured by a micrometer which he invented, furnished exact astronomical data. In 1860 he went to Spain with the "Himalaya" Expedition, and was successful in obtaining a series of photographs of the total eclipse of the sun on July 18th. In conjunction with Professor Balfour Stewart and Mr. B. Loewy, he published "*Researches in Solar Physics*," founded on observations made at the Kew Observatory under his directions. He also took an active part in making the preparations for the photographic observation of the transit of Venus in 1874.

Mr. de la Rue established a private observatory at Cranford, Middlesex, but it was dismantled in 1873, and the instruments presented to the University of Oxford. He acted as juror and reporter in the Department of Class XXIX. in the Great Exhibition of 1851, was a juror in Class X. of the Paris Exhibition of 1855, and presided over Section B, Class XXVIII. of the Exhibition of 1862. He has held office in several societies. He acted for some time as Secretary of the Royal Astronomical Society, of which he was also President from 1864 to 1866. He was President of the Chemical Society from 1867 to 1869 and again in 1879-80, and was till his death one of its Vice-Presidents. He was for many years President of the London Institution, from which he retired and became Secretary of the Royal Institution in 1878, but resigned the post in 1882. He was a corresponding member of many foreign scientific societies.

Mr. de la Rue was for several years a Member of the Kew Committee and also of the Meteorological Council. He was elected Chairman of the Kew Committee on the death of Sir E. Sabine in 1888.

He was elected a Fellow of this Society on April 17th, 1867.

He died on April 19th, 1889, aged 74.

J. G. GAMBLE.—The Society has lost a sincerely appreciative as well as a hard working Fellow by the death, of typhoid fever, at the age of 47, of Mr. John George Gamble, M.A., M.Inst.C.E., which took place on November 7th, 1889, at Dublin, where he held the appointment of Chief Hydraulic Engineer to the Government, and where in regard to the important schemes on which he was engaged his loss will be much felt.

Mr. Gamble was a man of considerable scientific and other attainments, having distinguished himself at Oxford by taking high honours both in the Classical and Mathematical Schools, and it may be mentioned that he there obtained the Gold Medal for the Johnson Memorial Prize Essay in 1871, the subject of the Essay being "The Laws of Wind."

He subsequently became a pupil to Sir John Hawkshaw, the eminent Civil Engineer, and while with him he was engaged in connection with the carrying out of important docks and other works, and he communicated papers which were read before the Institution of Civil Engineers in 1875, and the British Association in 1872, on the Brighton Intercepting and Outfall Sewers, of which work Mr. Gamble was the Resident Engineer under Sir J. Hawkshaw. He also acted as one of the local secretaries to the Mechanical Science section of the British Association at the Brighton Meeting in 1872.

After being engaged on an important investigation under Sir J. Hawkshaw on the Harbours of Brazil, he became in 1875 Chief Hydraulic Engineer to the Government of the Cape of Good Hope, where he designed and executed important works for domestic water supply, irrigation, and storage of water; and his reports in this capacity, extending over the period 1876-85, contain many valuable papers on these subjects.

Soon after his arrival in the Colony Mr. Gamble recognised the important bearing of Meteorological phenomena on the work of the Hydraulic Engineer, particularly as exemplified in the results of observations of temperature and rainfall, on which subjects he wrote several papers of considerable interest and value.

He found at the commencement that there was a great deficiency of records of rainfall; those, however, which existed were analysed, and in 1878 we find that a paper was contributed by him to the South African Philosophical Society, giving a list of 28 Rainfall stations, and in connection with which four seasonal maps were exhibited.

A complete list of the papers written by him on Meteorological and other subjects would occupy too much space, but we may mention that on the "Rainfall of South Africa," contained in the *Quart. Jour. R. Met. Soc.* Vol. VII. p. 8, which gives some account of the state of Meteorological knowledge in South Africa previously existing, and of the steps taken by Government to improve it; and as conducing to this end much might be said as to the effect of Mr. Gamble's influence in arousing interest in the subject, and in infusing vitality into the operations.

He became in 1877, and continued until his death, a Member of the Meteorological Commission which had existed for some years previously to his arrival in the Colony, and at some of the works carried out by him in exceptional localities observations established by him of evaporation and other matters have given interesting results.

Some of the more important of Mr. Gamble's labours in connection with this subject, are the Tables of average Rainfall from 75 stations, being all those in the Colony at which records had been kept for at least 5 years, contained in the *Met. Com. Rep.* for 1888, diagrams plotted from which were published in the Report of the succeeding year.

At the Colonial Exhibition held in South Kensington in 1886 Monthly and Yearly Maps of the Mean Rainfall of the Cape Colony by Mr. Gamble were exhibited, and these were subsequently reproduced in the *Met. Com. Rep.* for that year, which also includes the Rainfall Returns, which had in these few years increased to 275 stations.

Another was a Catalogue of printed books and papers relating to the Climate and Meteorology of South Africa, contributed to the *South African Phil. Soc.* Vol. II. Part II.

Mr. Gamble was elected President of the above-named Society for the year 1881-2, on which occasion his address was on "The Barometer and the Winds."

Another interesting paper on "Water Supply in the Cape Colony" was printed in Vol. XC. of the *Min. Proc. Inst. C.E.*

In addition to his other subjects of interest, Mr. Gamble paid much attention to the subject of higher Education in the Colony.

He was an examiner and a Member of Council of the Cape University, in the work connected with which he took a large share, and the high degree of culture possessed by him, as well as the assiduity with which he applied himself to matters in which he took part, rendered his departure from the Colony a loss deeply deplored in many quarters.

Mr. Gamble was exceedingly conscientious, and he carried out with great energy and ability all he undertook; he was also exceedingly unassuming in his manners, although his knowledge extended over a wide range of subjects, and his memory will long be highly esteemed by a large circle of friends.

He was elected a Fellow of this Society on February 18th, 1880.

PROF. ELIAS LOOMIS was born on August 7th, 1811, at Willington, Connecticut. He was appointed Tutor at Yale College in 1838, but he spent a year, 1836-7, in Paris. On his return he held professorships in various colleges till 1860, when he was appointed Professor of Astronomy at Yale, an office which he held till his death on August 15th, 1889.

Prof. Loomis began publishing papers on storms in 1838, and his *Smithsonian Contribution* "On certain Storms in Europe and America, December 1836," was dated 1839. He wrote a number of school text-books of science. His *Treatises* on Meteorology and Astronomy are both well known in this country. His books are said to have attained a sale of 500,000 copies.

His most important work has been the preparation of his "Contributions to Meteorology," originally issued in *Silliman's Journal*. He was engaged up to the time of his death in a republication of these in quarto form.

He was elected an Honorary Member of this Society on June 17th, 1874.

EDWARD WINDUS MATHEW was the son of Mr. Nathaniel Mathew, of Wern, Carnarvonshire, and was born in 1812. He was a J.P. and D.L. for county Carnarvon, and was for some time Major-commanding the 4th Carnarvonshire Rifle Volunteers. His family were connected with large slate quarries in Wales, and carried out extensive quarry works in conjunction with Lord Penrhyn.

He removed to Guildford about ten years ago, where he took a lively interest in meetings of a social and political nature.

He was a devoted student of Meteorology, and contributed largely to the scientific journals.

He died on October 26th, 1889, in the seventy-seventh year of his age.

He was elected a Fellow of this Society on June 15th, 1881.

JAMES MUIR was born at Glasgow on May 31st, 1817, his father being the Rev. William Muir, D.D., LL.D., a minister of the Established Church of Scotland, afterwards of St. Stephen's, Edinburgh, and one of Her Majesty's chaplains in Scotland. Mr. Muir was educated at Edinburgh, where he attended first the High School, and then the Academy, completing his education at the University. Whilst awaiting an opening that would form an introduction to civil engineering, he assisted Mr. John Scott Russell, under whom he had formerly studied, in investigating the laws that govern wave motion and that affect the movement of floating bodies through water. At the age of eighteen he came to London, and was articled to the Messrs. J. and G. Rennie of Blackfriars. There Mr. Muir was employed in the office and workshops until the year 1841, when he entered the service of the New River Company, London, as assistant to Mr. W. C. Mylne, F.R.S. Whilst so engaged he designed a water-meter which was found to be a great improvement upon the then existing apparatus, and he was thereupon highly commended by the Directors of the Company for his ingenuity.

On the resignation of Mr. Mylne in 1859, Mr. Muir was appointed Engineer to the Company. From this time until his retirement he was energetically occupied in extending the sources of the supply, in improving the means available for its distribution, and in maintaining its quality at the highest standard of purity attainable. In order to meet the heavy demands that arose from extension of building, and the increased use of water for sanitary purposes, he sank numerous deep wells into the chalk between Hertford and London. By deep boring at two of the wells, viz. those at Ware and at Turnford, he solved the question, so far as the country northward of London is concerned, of the possibility of finding a new source of water for the supply of the Metropolis in the Lower Greensand, a question that was formerly much discussed by geologists. At both of the places named the stratum sought was found to exist, but in a very attenuated form and quite devoid of water.

A matter that frequently engaged his attention was the enlargement of the channel of the New River along which the supply is conveyed to town. This artificial watercourse having been formed more than 270 years since, has from time to time needed much alteration to fit it for present requirements. In pursuit of this object, Mr. Muir renewed the aqueduct at places where diversion of the stream was required; added auxiliary conduits where the sectional area was restricted, and by various ingenious methods largely increased the carrying capacity of the channel. The rapid growth of the northern suburbs of London early necessitated the construction of an enlarged

filtering and pumping station at Hornsey, where under his direction provision was made for lifting large quantities of water to reservoirs on the tops of the ridges extending from Hornsey to Hampstead. Among the number of these newly-made Reservoirs a pair at Crouch Hill, having a total capacity of 12,000,000 gallons, were constructed in the face of considerable engineering difficulties arising from the treacherous nature of the sub-soil.

Shortly after his appointment as Engineer to the Company Mr. Muir re-arranged the whole system of distributing mains throughout the town districts, forming zones of supply at the various levels corresponding to several reservoirs. This involved the laying of a great number of pipes varying in size up to 86 inches in diameter, and the arrangement of many new connections, the work being often carried on under great disadvantages owing to the crowded state of underground London, and the many interests, municipal and other, that must necessarily be consulted.

In 1872, when the regulations for prevention of waste of water were framed by the Board of Trade, as prescribed by the Metropolis Water Act of the preceding year, he took an active part in collecting materials that would be of service in their compilation, his aim being to obtain for London the advantages that are possessed by most of the larger municipal Corporations, in the way of ability to prevent waste of water without restricting its use for domestic purposes. With this end in view he also took great interest in all newly-invented water fittings, whether for domestic or public use. Among the many details appertaining to the various structures and appliances used in waterworks, which had his studious and indefatigable attention, may be mentioned the arrangement of the filtering medium in filter beds. He first introduced the method, which has now become general, of forming small drain channels of common bricks laid dry in rows at the bottom of the bed, with a closely-paved covering of the same above, upon which shingle for supporting the sand rests.

In the course of many inquiries concerning such matters as Water Supply, Pollution of Rivers, &c. that have from time to time been conducted by Royal Commissions and Parliamentary Committees, Mr. Muir was often called upon to appear as a witness, in which capacity he greatly excelled, impressing all who heard him by the readiness of his replies, and by the full and lucid, but at the same time concise, manner in which he answered questions, whether from friendly or opposing counsel. Another direction in which he showed talent to a remarkable degree was in dealing with financial affairs, for which he evinced a special aptitude. Thus it frequently happened that he was able to effect considerable economies, without in any way lessening the value of the final results.

In the year 1882, having fallen into ill-health, Mr. Muir was relieved from active duty, and accepted the post of Consulting Engineer to the Company. In the succeeding year he was elected a Director, and, notwithstanding that he then resided at Bournemouth, was unremitting in his attendance at the weekly Board Meetings until about midsummer of the year 1888, when he was seized with the illness which, after a long and painful course, terminated in his death on January 4th, 1889.

Mr. Muir was most conscientious and scrupulous in all his dealings, and earnestly strove to imbue his subordinates with his own intense devotion to duty. He combined a kindly and gentle disposition with great firmness and love of discipline. His judgment was much esteemed by those who were professionally associated with him, whilst his courteous manner and readiness to assist with judicious counsel made him respected and trusted by all who knew him. In private life he was always deeply interested in works of benevolence, to some of which he unobtrusively devoted himself, especially bestowing much time to the instruction and improvement of the young.

He was elected a Fellow of this Society on May 15th, 1878.

WILLIAM PARKES was born near Gloucester on October 6th, 1822. He was educated at Bristol College and at University College, London, and being at that time of a delicate constitution, the doctors advised him to adopt a profession which would give him as much outdoor life as possible. With this view he entered the office of Mr. Hemming, an engineer in Bristol, in 1838, and after being there for a certain time, he obtained employment under the contractor who was then constructing the Great Western Railway.

In 1845 he entered the office of the late Mr. James Walker, Past-President, Inst. C. E., and while with him assisted in the preparation of the surveys and plans for various large works.

In 1847 he was sent to Alderney by Mr. Walker to report on the proposed harbour there, and, on the commencement of the works shortly afterwards, he acted as Resident Engineer under Mr. Walker, holding the position for two years.

In 1849 Mr. Parkes returned to London, and early in 1850 he started an office of his own in Parliament Street. He still retained his connection with Mr. Walker, who employed him to make reports and surveys for the River Dee Improvement scheme and other works of a similar nature in England, besides which he made surveys for various railways which were then in contemplation.

In 1858 he was asked by Mr. (now Sir) C. H. Gregory to go to Italy to superintend the work of draining Lake Fucino, but after spending a considerable amount of time and trouble the work was taken out of the hands of the English Engineers, and Mr. Parkes returned to England. About this time Mr. Walker having been requested to report on the proposal to construct a harbour at Kurrachee, Mr. Parkes was deputed to go to India to make surveys and gather materials for the report, and on his return he prepared the plans for the breakwater in conjunction with Mr. Walker, but no work was started at Kurrachee for some years afterwards. In 1860 Mr. Parkes was employed in the designing and erection of several lighthouses in the Red Sea and the Cerigo lighthouse in the Mediterranean. In 1864 he presented to the Institution of Civil Engineers a description of this work, for which he was awarded a Telford premium.¹ He also superintended the construction in

¹ *Minutes of Proceedings Inst. C.E.*, Vol. XXIII. p. 1.

England of the lighthouse which was erected on the Island of Sombrero in the West Indies.

In 1868 he went out to Kurrachee, and the construction of the breakwater was commenced, Mr. W. H. Price being left in charge of the work as Resident Engineer, and Mr. Parkes returning to England with the appointment of Consulting Engineer. This breakwater, which was completed in 1873, was the first instance of the now well-known "sloping-block" system being carried out on a large scale.

In 1873 Mr. Parkes was instructed to go to Madras to report as to the formation of a harbour at that place, and in 1875 he submitted to the Government his proposed design, consisting of two parallel breakwaters running out from the shore and turned round at the ends. This was accepted, and work was started there in 1876, Mr. Parkes going out to Madras to organise the staff and set the works going. The harbour was on the point of completion in 1882, when a cyclone visited Madras, which had the effect of destroying the outer arms of the breakwater, and a Committee of leading Engineers was appointed in London to consider the best way of restoring the works, and on their recommendations the ruined portions of the breakwaters were ordered to be reconstructed on a strengthened design, which work is still in progress.

At the time of his death Mr. Parkes was still acting as Consulting Engineer to the Madras Harbour Works, and was also the Engineering agent for the supply of wharf materials, dredging plant, &c. to the Kurrachee Port Trust, for the inner improvement of the harbour.

His sudden death from heart disease at his house at Surbiton on February 2nd, 1889, caused the greatest sorrow, not only to his immediate relatives, but to a large circle of friends both in London and at Surbiton, where for many years he had taken a prominent part in the management of local affairs.

He was elected a Fellow of this Society on June 15th, 1864.

STEPHEN JOSEPH PERRY was born in London on August 26th, 1833, and was the son of Mr. Stephen Perry, a member of a well-known firm in Red Lion Square. He received his early education at Gifford Hall School, and then went to France to study at the College at Douay, where he was so successful in his mathematical work as to carry off the first prize. From Douay he proceeded to the English College at Rome for theological training, as he was destined for the priesthood, and in 1853 he entered the Society of Jesus.

It was in 1856 that Father Perry first came to Stonyhurst College, to go through the usual course of mental philosophy and physical science. His special aptitude for mathematics was soon perceived, and in the same year he was appointed to assist the Rev. A. Weld, who was then Director of the Observatory. In 1858, on matriculating at the London University, he went up for mathematical honours, taking the sixth place. After this he was sent to London for a year to study under Professor De Morgan, and then for

another year to Paris, where he attended the mathematical lectures of Liouville, Delaunay, Serrat, Cauchy, and Bertrand.

In the autumn of 1860 he returned to Stonyhurst, being appointed Professor of Mathematics and Director of the Observatory, as successor to Father Weld, who had held that position for many years. In the autumn of 1863 he left to complete his theological course at St. Beuno's College, in North Wales, where he was ordained priest in 1866; and when all his studies were completed he came back finally to Stonyhurst in 1868 to resume charge of the Observatory, which he continued to direct until the day of his death.

Father Perry carried out a magnetic survey of the west of France in 1868, and of Belgium in 1871; the results of which were published in the *Philosophical Transactions*. He also took part in a number of astronomical expeditions sent out from this country. In 1870 he was chosen as chief of the expedition to Cadiz to observe the total eclipse of the sun; and in 1874 was appointed to the command of the expedition to Kerguelen Island to observe the transit of Venus. In 1882 he again took charge of an expedition to the South-west coast of Madagascar to observe the transit of Venus. He also went out to observe solar eclipses in the West Indies on August 29th, 1886, and at Pagost, on the Volga, on August 19th, 1887.

Father Perry took charge of the Royal Astronomical Society's expedition to French Guiana to observe the total solar eclipse on December 22nd, 1889. The weather, however, was wet and very unhealthy, and he fell ill with dysentery. He managed to bear up and take some successful photographs, but he rapidly became worse and died on the 27th.

He was elected a Fellow of this Society on April 21st, 1869, and served on the Council in 1874-75. He was elected a Fellow of the Royal Society in 1874, and received the honorary degree of D. Sc. from the Royal University of Ireland in 1886.

JAMES SIMPSON, the eldest son of the late Mr. James Simpson, Past-President of the Institution of Civil Engineers, was born on January 10th, 1829, at Thames Bank, Chelsea, the residence of his father, who was at that time Engineer to the Chelsea Waterworks Company. He was educated at St. Peter's Collegiate School, Eaton Square, and at Dr. Lord's private school at Tooting. In 1846 he was articled to Messrs. Burns and Bryce, Architects, Edinburgh, where he lived with the late Dr. John Brown.

Returning to London in 1851 he joined his father, who was at that time engaged in an extensive practice as a civil engineer, and superintended for him the execution of several important works, amongst others the construction of the waterworks at Carlisle and the extension of the Chelsea Waterworks Company to Surbiton, Surrey. In 1857 he joined the firm of Simpson and Company, manufacturing engineers, taking a leading part in the introduction of improved pumping-plants, especially the Woolf Compound Pumping-Engines, and in the construction of waterworks abroad.

For the past few years failing health prevented close attention to business,

although to the last he took a lively interest in all matters connected with engineering. He was much respected by those in his employ, as well as by others with whom he was associated, not only for his kindness of disposition, but also for his readiness to impart knowledge. His health gradually failing, he died at Brighton on May 11th, 1889, and was buried at Brompton Cemetery.

He was elected a Fellow of this Society on April 20th, 1870.

APPENDIX IV.

BOOKS PURCHASED DURING THE YEAR 1889.

- BECCARIA, G.—A treatise upon artificial electricity. 4to. (1776.)
 COWE, REV. J.—The meteorological register kept at Sunbury Vicarage, Middlesex, 1795-1839. Foolscep Folio. (1889.)
 ENCYCLOPÆDIA BRITANNICA.—Ninth Edition. Index. 4to. (1889.)
 INSTITUT MÉTÉOROLOGIQUE DANOIS ET LE DEUTSCHE SEEWARTE.—Cartes synoptiques journalières du temps, embrassant le Nord de l'Atlantique et une partie des continents avoisinants, June to Nov. 1885. Folio. (1888.)
 OFFICIAL YEAR BOOK OF THE SCIENTIFIC AND LEARNED SOCIETIES of Great Britain and Ireland, 1889. 8vo. (1889.)
 SMYTH, PROF. C. PIAZZI, F.R.S.—Teneriffe, an astronomical experiment. 8vo. (1858.)
 "THE TIMES" REGISTER OF EVENTS in 1888. 8vo. (1889.)

APPENDIX V.

DONATIONS RECEIVED DURING THE YEAR 1889.

Presented by Societies, Institutions, &c.

- ADELAIDE, GOVERNMENT OBSERVATORY.—Minutes of Proceedings of the Intercolonial Meteorological Conference held at Melbourne, 1888.
 ALLAHABAD, METEOROLOGICAL OFFICE.—Annual Statement of the Rainfall in the North-western Provinces and Oudh, 1888.
 BATAVIA, MAGNETICAL AND METEOROLOGICAL OBSERVATORY.—Observations, Vols. VIII. 1883-5, X. 1887, and XI. 1888.—Rainfall in the East Indian Archipelago, 1887 and 1888.
 BAYONNE, SOCIÉTÉ DE CLIMATOLOGIE PYRÉNÉENNE.—Bulletin, 1re Année, Nos. 3, 4, and 6 to 11; 2me Année, Nos. 1-9.
 BERLIN, DEUTSCHE METEOROLOGISCHE GESELLSCHAFT.—Meteorologische Zeitschrift, Dec. 1888 to Dec. 1889.
 BERLIN, GESELLSCHAFT FÜR ERDKUNDE.—Zeitschrift, Nos. 139-142.—Verhandlungen, Band XVI. Nos. 1-9.
 BERLIN, KÖNIGLICH PREUSSISCHES METEOROLOGISCHES INSTITUT.—Ergebnisse der meteorologischen Beobachtungen im Jahre 1887, and 1889, Heft. 1.—Instruktion für die Beobachter an den meteorologischen Stationen II. III. und IV. Ordnung.
 BOMBAY, METEOROLOGICAL OFFICE.—Brief Sketch of the Meteorology of the Bombay Presidency in 1887-1888.—Magnetical and Meteorological Observations, 1887.
 BRISBANE, CENTRAL WEATHER BUREAU.—Brisbane Observatory: Meteorological Synopsis, Feb. 1883 to June 1889.—Daily Weather Charts of Australia, Oct. 26, 1888, to July 24, 1889.—Meteorological Instructions. By C. L. Wragge.—Meteorological Report for 1887.—Minutes of Proceedings of the Intercolonial Meteorological Conference held at Melbourne 1888.—Preliminary Report of the Government Meteorologist for the year 1887.—Summaries of Rainfall, Jan. 1888 to June 1889.—Telegraphic Code and special notice to observers.—The Climate of Queensland, Jan.-June 1889.
 BRISBANE, GENERAL REGISTER OFFICE.—Annual Report of the Registrar-General on Vital Statistics, 1888.—Report on the Vital Statistics, Oct. 1888 to Sept. 1889.

BRUSSELS, ACADEMIE ROYALE.—Annuaire 1888 and 1889.—Bulletins, 3me Série, Tome XIV.-XVII. 1887 to 1889.

BRUSSELS, INSTITUT NATIONAL DE GÉOGRAPHIE.—Bulletin Météorologique, Dec. 1888 to Nov. 1889.

BRUSSELS, OBSERVATOIRE ROYAL DE BRUXELLES.—Annuaire, 1889.

BUKHAREST, INSTITUT MÉTÉOROLOGIQUE DE ROUMANIE.—Annales, Tome III. 1887.

CAIRO, SOCIÉTÉ KHÉDIVIALE DE GÉOGRAPHIE.—Bulletin, IIIe Série, Nos. 2-4.

CALCUTTA, METEOROLOGICAL OFFICE.—Indian Daily Weather Reports, Dec. 6, 1888, to Dec. 7, 1889.—Indian Meteorological Memoirs, Vol. III. Pts. 3 and 4, and Vol. IV. Pts. 5 and 6.—Registers of Original Observations, reduced and corrected, Aug. to Dec. 1888.—Report on the Administration of the Meteorological Department of the Government of India in 1887-88.—Report on the Meteorology of India in 1887.—Weather Charts of the Arabian Sea and the adjacent portion of the North Indian Ocean.

CAMBRIDGE, ASTRONOMICAL OBSERVATORY OF HARVARD COLLEGE.—Annals, Vol. XX. Pt. 1. Observations at Blue Hill Meteorological Observatory, 1887.

CAMBRIDGE, NEW ENGLAND METEOROLOGICAL SOCIETY.—Bulletin, Dec. 1888 to Nov. 1889.

CAPE TOWN, METEOROLOGICAL COMMISSION.—Report, 1888.

CHEMNITZ, KÖNIGL. SÄCHSISCHES METEOROLOGISCHES INSTITUT.—Jahrbuch, 1887.

CHRISTIANIA, NORSKE METEOROLOGISKE INSTITUT.—Jahrbuch, 1887.

COLOMBO, SURVEYOR-GENERAL'S OFFICE.—Report on the Meteorology of Ceylon for 1888.

COPENHAGEN, DANSKE METEOROLOGISKE INSTITUT.—Bulletin Météorologique du Nord, Dec. 1888 to Nov. 1889.—Meteorologisk Aarbog, 1886, 1887, and 1888, Pts. 1 and 3.—Observations Internationales Polaires. Expédition Danoise. Observations faites à Godthaab. Tome II. Livraison 2.

CORDOBA, ACADEMIA NACIONAL DE CIENCIAS.—Boletín, Tome XI. pt. 3.

CORDOBA, OFICINA METEOROLÓGICA ARGENTINA.—Ligeros apuntes sobre el clima de la República Argentina. Por G. G. Davis.

CRACOW, K. K. STERNWART.—Meteorologische Beobachtungen, Oct. 1888 to Oct. 1889.

CROYDON, MICROSCOPICAL AND NATURAL HISTORY CLUB.—Daily Rainfall in the Croydon District, Dec. 1888 to Nov. 1889.

DORPAT, OBSERVATORIUM.—Bericht über die Ergebnisse der Beobachtungen an den Regenstationen, 1887.—Meteorologische Beobachtungen, May to Dec. 1888.

DUBLIN, GENERAL REGISTER OFFICE.—Annual Report of the Registrar-General (Ireland), 1888.—Weekly Returns of Births and Deaths, Vol. XXV. No. 52 to Vol. XXVI. No. 51.

DUBLIN, ROYAL DUBLIN SOCIETY.—Scientific Proceedings, Vol. VI. Pts. 3-6.—Scientific Transactions, Vol. IV. Pts. 2-5.

DUBLIN, ROYAL IRISH ACADEMY.—Proceedings. Third Series, Vol. 1, No. 1.—Transactions, Vol. XXIX. Pts. 3-11.

EDINBURGH, GENERAL REGISTER OFFICE.—Quarterly Returns of the Births, Deaths and Marriages registered in Scotland for the four quarters ending Sept. 30, 1889.

EDINBURGH, ROYAL SCOTTISH GEOGRAPHICAL SOCIETY.—Scottish Geographical Magazine, 1889.

EDINBURGH, SCOTTISH METEOROLOGICAL SOCIETY.—Journal, Third Series, Nos. 5 and 6.

FALMOUTH, ROYAL CORNWALL POLYTECHNIC SOCIETY.—Report, 1888.

FIUME, I. R. ACCADEMIA DI MARINI.—Meteorological Observations, Oct. 1888 to Oct. 1889.

GENEVA, OBSERVATORY.—Résumé Météorologique de l'année 1888 pour Genève et le Grand Saint-Bernard, par A. Kammermann.

GENEVA, SOCIÉTÉ DE GÉOGRAPHIE.—Le Globe. Bulletin, Tome XXVIII. Nos. 1 and 2.

GENEVA, SOCIÉTÉ DE PHYSIQUE ET D'HISTOIRE NATURELLE.—Limnimètre Enregistreur Transportable. Observations à la Tour de Peilz près Vevey. Par M. E. Sarasin.—Pénétration de la lumière du jour dans les eaux du lac de Genève et dans celles de la Méditerranée. Par MM. H. Fol et E. Sarasin.—Recherches sur la transparence des eaux du Lac Léman, 1884-1886.—Sur la couleur de l'eau. Par J. L. Soret.

GLASGOW, PHILOSOPHICAL SOCIETY.—Proceedings. Vol. XX. 1888-9.

GREENWICH, ROYAL OBSERVATORY.—Report of the Astronomer Royal to the Board of Visitors, June 1889.

HALLE, K. LEOPOLDINA-CAROLINISCHE DEUTSCHE AKADEMIE DER NATURFORSCHER.—Leopoldina, Vol. XXIV.

HAMBURG, DEUTSCHE SEEWARTE.—Aus dem Archiv, 1885 to 1888.—Bericht über die Verhandlungen des internationalen meteorologischen Comité's; Zürich 1888.—Deutsches meteorologisches Jahrbuch für 1887.—Deutsche ueberseeische meteorologische Beobachtungen, Heft. II.—Ergebnisse der meteorologischen Beobachtungen im Systeme der Deutschen Seewarte für die Lustren 1876-80 und 1881-5 sowie das

Dezennium 1876-85.—Monatsbericht, Sept. 1888 to May 1889.—Vierteljahrs-Wetterrundschaу an der Hand der täglichen synoptischen Wetterkarten für den Nord-Atlantischen Ocean, Band I. Heft. 5; Band II. Heft. 1 and 2.—Wetterbericht, 1889.

HONG KONG, OBSERVATORY.—Observations made in the year 1889.

KARLSRUHE, CENTRALEUREAU FÜR METEOROLOGIE UND HYDROGRAPHIE IM GROSSEHERZOGTHUM BADEN.—Die Ergebnisse der meteorologischen Beobachtungen im Jahre 1888.

KEW, OBSERVATORY.—Report of the Kew Committee for the year ending Oct. 31, 1888.

LISBON, OBSERVATORIO DO INFANTE DON LUIZ.—Annaes, Vols. XXIII.-XXIV. 1885-6.—Observações dos Postos Meteorológicos, 1885.

LISBON, SOCIEDADE DE GEOGRAPHICA.—Boletim, 7a Serie, No. 11, to 8a Serie, No. 6.

LONDON, BRITISH ASSOCIATION.—Report 1888.

LONDON, COLONIAL OFFICE.—Annual Report of the Director of the Royal Alfred Observatory, Mauritius, 1887.—Meteorological Report, Straits Settlements, 1888.—Observations made at the Hong Kong Observatory, 1888.—Report on great storm of 29th and 30th May 1889 at Hong Kong.

LONDON, GENERAL REGISTER OFFICE.—Annual Summary of Births, Deaths, and causes of Death in London, and other great towns, 1888.—Quarterly Returns of Marriages, Births, and Deaths for the four quarters ending Sept. 30, 1889.—Weekly Returns of Births and Deaths, Vol. XLIX. No. 52 to Vol. L. No. 51.

LONDON, GEOLOGICAL SOCIETY.—Quarterly Journal, Nos. 177 to 180.

LONDON, INDIA OFFICE.—A Manual of Forestry, by W. Schlich, Vol. I.

LONDON, INSTITUTE OF CHEMISTRY OF GREAT BRITAIN AND IRELAND.—Register, 1889.

LONDON, INSTITUTION OF ELECTRICAL ENGINEERS.—Journal, Nos. 75 to 81.

LONDON, JUNIOR ENGINEERING SOCIETY.—Programme, List of Members, Rules, and Report of Eighth Session.

LONDON, METEOROLOGICAL OFFICE.—Daily Weather Reports, 1889.—Directions for adjusting and using the Sunshine Recorder.—Hourly Reading, 1886.—Meteorological Observations at stations of the Second Order for the year 1885.—Quarterly Weather Report, 1879, Pt. 4, and 1880, Pt. 1.—Report of the Meteorological Council to the Royal Society for the year ending March 31st, 1888.—Report of the fourth meeting of the International Meteorological Committee, Zurich, Sept. 1888.—Report on Hygrometric Methods. By W. N. Shaw.—Weekly Weather Report, Vol. V. No. 51 to Vol. VI. No. 50.—Annual Reports of the Colonial Museum and Laboratory, New Zealand, 1884-7.—Handbook of New Zealand. By Dr. J. Hector, F.R.S.—Monthly Tables of Rainfall in South Australia, 1887.—Rainfall in South Australia and the Northern Territory, 1888.—Report of the Royal Society of Tasmania, 1883.—Meteorological Observations taken at the Government Lock Hospital, Victoria, Hong Kong, 1881-3.—Results of Meteorological Observations at the Anuradhapura Kachcheri (1880), Batticaloa (1881), Jaffna (1880), and Trincomalee (1881) in Ceylon.—Return of Rainfall in Ceylon, 1885.—Results of Meteorological Observations in Ceylon, 1886-9.—Barometric hypsometry and reduction of the barometer to sea level. By W. Ferrel.—Journal and Proceedings of the Hamilton Association, Canada, Vol. 1, Part 2, 1884-5.—Meteorological Observations made at Southport, Oct. 27, 1888, to Mar. 29, 1889.—Meteorological Return for Trinidad, Jan. to Nov. 1888, and Jan. to Mar. 1889.—Bulletin quotidien de l'Algérie, Dec. 1, 1888, to Oct. 31, 1889.—Service Central Météorologique de l'Algérie; Bulletin Mensuel, March 1888.—Résumé des travaux de l'expédition Polaire Danoise Internationale.—Sur la quatrième campagne scientifique de "l'Hirondelle." Par S. A. le Prince Albert de Monaco.—Sur l'emploi de masses pour des recherches zoologiques en eaux profondes. Par S. A. le Prince Albert de Monaco.—Ergebnisse der Beobachtungen der meteorologischen Stationen des Grossherzogthums Baden, 1887.—Ombrometrische Beobachtungen der vom böhmischen Forstvereine in den Fürsten Böhmens in verschiedenen Seehöhen und Expositionen errichteten Stationen, 1879-80.—Sur un dispositif destiné à éclairer les eaux profondes. Par M. P. Regnard.—Verhandlungen der K. K. zoologisch-botanischen Gesellschaft in Wien. Band XXXVIII. Pts. 1 and 2, 1888.—Gemiddelde barometerstand en stormen rond Afrika's Zuidpunt.—Géographie physique de la Partie Equatoriale de l'océan Atlantique. Par M. Toynbee.—Guide pour l'usage des cartes des vents et des courants du Golfe de Guinée. Par M. De Brito Capello.—Jahrsbericht der Naturforschenden Gesellschaft in Emden, 1886-88.—Vents et courants routes générales extrait des 'Sailing Directions' de Manry et des travaux les plus récents. Par M. C. Floix.—Cartes des vents sur la côte est de l'Amérique du Sud, de l'Amazon à la Plata.—Maandelijksche zeilaanwijzingen van Java naar het Kanaal.—Zeilaanwijzingen van Java naar het Kanaal, Pts. I. and II.—Reizen van Australie naar Java.—Gemiddelde barometerstanden, op de route van de linie naar het Kanaal.—Algemeene windkaart Zamenges teld uit Amerikaansche en Hollandsche waarnemingen.—Maurijs wind-kaart voor het Oostelijk gedeelte van den Noorder Atlantischen Oceaan.—Gemiddelde barometerstandken, op der route van de Kaap de Goede Hoop naar de linie.—Atlas behoorende bij de uitkomsten van

wetenschap en ervaring aangaande de winden en zeestroomingen in sommige gedeelten van den oceaan, 1863.—De wet der stormen getsetst aan latere waarnemingen als eene uitkomst van wetenschap en ervaring, aangaande winden en zeestroomingen in sommige gedeelten van den oceaan, 1862.—Korte toelichtingen behoorende bij het Kompas-Journaal.—Mededeelingen uit de journalen aangaande bijzondere meteorologische verschijnselen havens banken enz.—Onderzoekingen met den zeethermometer, als uitkomsten van wetenschap en ervaring aangaande de winden en zeestroomingen in sommige gedeelten van den oceaan, 1861.—Toetsing eener methode, waar door ten allen tijde de afwijking van het kompas kan worden gevonden. Door Lieut. W. Van Hasselt.—Uitkomsten van wetenschap en ervaring aangaande winden en zeestroomingen in sommige gedeelten van den oceaan. Five Vols. 1856-9.—Verzameling van kaarten inboudende eene procentagewijze opgave omtrent storm, regen, donder en mist, grootendeels getrokken uit de jongste waarnemingen onzer Nederlandsche Zeelieden, 1862.

LONDON, PHYSICAL SOCIETY.—Proceedings, Vol. X. Pts. 1 and 2.

LONDON, ROYAL AGRICULTURAL SOCIETY.—Journal, Second Series, Vol. XXV.

LONDON, ROYAL ASTRONOMICAL SOCIETY.—Monthly Notices, Vol. XLIX. No. 2 to Vol. L. No. 1.

LONDON, ROYAL BOTANIC SOCIETY.—Quarterly Record, 1889.

LONDON, ROYAL INSTITUTION OF GREAT BRITAIN.—Proceedings, No. 82.

LONDON, ROYAL SOCIETY.—Proceedings, Nos. 272 to 283.

LONDON, SANITARY INSTITUTE OF GREAT BRITAIN.—Transactions, Vol. IX.

LONDON, SOCIETY OF ARTS.—Journal, 1889.

MADRID, OBSERVATORIO.—Observaciones Meteorológicas, 1866-7.—Resumen de la observaciones meteorológicas efectuadas en la Peninsula, 1864-5.

MADRID, SOCIEDAD GEOGRÁFICA.—Boletín, Tomo XXV. No. 3 to Tomo XXVII. No. 3.

MAGDEBURG, WETTERWARTE DER MAGDEBURGISCHEN ZEITUNG.—Jahrbuch der meteorologischen Beobachtungen, 1888.

MANCHESTER, LITERARY AND PHILOSOPHICAL SOCIETY.—Memoirs and Proceedings, Fourth Series, Vol. II.

MANILA, OBSERVATORIO METEOROLÓGICO.—Curvas Meteorográficas, July 1883 to Dec. 1887.

MARLBOROUGH, COLLEGE NATURAL HISTORY SOCIETY.—Report for 1888.

MARSEILLES, COMMISSION MÉTÉOROLOGIQUE DU DÉPARTEMENT DES BOUCHES-DU-RHÔNE.—Bulletin Annuel, 1887.

MAURITIUS, ROYAL ALFRED OBSERVATORY.—Annual Report of the Director, 1887.—Mauritius Meteorological Results, 1887 and 1888.

MELBOURNE, GOVERNMENT OBSERVATORY.—Monthly Record of Results of Observations in Meteorology, Terrestrial Magnetism, &c., June 1888 to July 1889.

METZ, ACADEMIE.—Observations météorologiques faites à Metz, 1885.

MEXICO, OBSERVATORIO ASTRONÓMICO NACIONAL DE TACUBAYA.—Anuario, 1889.

MEXICO, OBSERVATORIO METEOROLÓGICO MAGNÉTICO CENTRAL.—Anales del Ministerio de Fomento de la República Mexicana, Tomo VIII.—Boletín Mensual, Tomo I. No. 8 to Tomo II. No. 1.—Resumen comparativo correspondiente a los años de 1887-1888.

MEXICO, SOCIEDAD CIENTÍFICA "ANTONIO ALZATE."—Memorias, Tomo II. núm. 10 and 11.

MICHIGAN, STATE BOARD OF HEALTH.—Principal Meteorological Conditions in Michigan in 1887.—Proceedings and Addresses at a Sanitary Convention held at Hastings, Michigan, Dec. 1888.—Ditto at Ludington, Michigan, July 11 and 12, 1889.—Ditto at Otsego, May 2 and 3, and Tecumseh June 6 and 7, 1889.—Report of the Secretary for the year ending June 30, 1888.

MILAN, R. OSSERVATORIA DI BRERA.—Confronti e verificazioni d' azimut assoluti in Milano con alcune note sulle antiche triangolazioni nei dintorni di questa città. Di M. Rajna.—Osservazione Meteorologiche, 1888.—Sulla distribuzione apparente delle stelle visibili ad occhio nudo di G. V. Schiaparelli.

MOSCOW, SOCIÉTÉ IMPÉRIALE DES NATURALISTES.—Bulletin, 1888, No. 4; 1889, Nos. 1 and 2.—Meteorologische Beobachtungen, July to Dec. 1888.

MUNICH, K. B. METEOROLOGISCHE-CENTRAL STATION.—Beobachtungen der meteorologischen Stationen im Kön. Bayern, Jahrgang X. Heft 3 to Jahrgang XI. Heft 2.—Temperaturmittel für Süddeutschland. Von K. Singer.—Übersicht über die Witterungsverhältnisse im Kön. Bayern, Dec. 1888 to Nov. 1889.

NATAL, OBSERVATORY.—Report of the Superintendent, 1888.

NEUCHÂTEL, SOCIÉTÉ NEUCHÂTELOISE DE GÉOGRAPHIE.—Bulletin, Tome IV. 1888.

NEWHAVEN, OBSERVATORY OF YALE UNIVERSITY.—Report for 1888-9.

NEW YORK, ACADEMY OF SCIENCES.—Transactions, Vol. VIII. Nos. 1 to 4.

NEW YORK, CENTRAL PARK OBSERVATORY.—Abstracts of Registers from Self-Recording Instruments, Dec. 1888 to Nov. 1889.—Annual Report, 1888.

OXFORD, RADCLIFFE OBSERVATORY.—Results of Meteorological Observations, 1885.

- PARIS, BUREAU CENTRAL MÉTÉOROLOGIQUE.—Bulletin International, 1893.
- PARIS, OBSERVATOIRE MUNICIPAL DE MONTSOURIS.—Annuaire, 1889.
- PARIS, SOCIÉTÉ MÉTÉOROLOGIQUE DE FRANCE.—Annuaire, Sept. 1898 to Aug. 1893.—Observations Météorologiques faites à Nijné-Taguisk (Monts Oural), 1852-3.
- PHILADELPHIA, AMERICAN PHILOSOPHICAL SOCIETY.—Proceedings, Nos. 128 and 129.—Subject Register of papers published in the Transactions and Proceedings.
- POLA, K. K. HYDROGRAPHISCHES AMT.—Meteorologische und magnetische Beobachtungen, Nov. 1888 to Oct. 1889.
- PONT-AU-PRINCE, OBSERVATOIRE MÉTÉOROLOGIQUE.—Bulletin, Dec. 1888 to Nov. 1889. (MS.)
- PRAGUE, KÖNIGL. BÖHM. GESELLSCHAFT DER WISSENSCHAFTEN.—Jahresbericht, 1895-88.—Sitzungsberichte, 1885, 1887, and 1888.
- PRAGUE, K. K. STERNWART.—Magnetische und meteorologische Beobachtungen, 1888.
- PUEBLA, OBSERVATORIO METEOROLÓGICO DEL COLEGIO DEL ESTADO.—Resumen Correspondiente a cada día, Jan. to Oct. 1889.—Resumen de 11 años de observaciones meteorológicas.
- RIO DE JANEIRO, OBSERVATOIRE IMPÉRIAL.—Revista do Observatorio, Dec. 1888 to Nov. 1889.
- ROME, UFFICIO CENTRALE METEOROLOGICO E GEODINAMICO ITALIANO.—Annali, Serie II. Vol. VII. Pts. 1-4 and Vol. VIII. Pts. 1-3.
- SAN FERNANDO, INSTITUTO Y OBSERVATORIO DE MARINA.—Anales, Seccion 2a, Observaciones Meteorológicas, Año 1887 and 1888.
- SAN JOSÉ, INSTITUTO METEOROLOGICO NACIONAL.—Boletín Trimestral, No. 4.
- SANTIAGO, OFICINA HIDROGRÁFICA DE CHILE.—Anuario Hidrográfico, Año XIII.—Exploraciones geográficas e hidrográficas de José de Moraleda i Montero.
- STOCKHOLM, L'ACADÉMIE ROYALE DES SCIENCES DE SUÈDE.—Observations Météorologiques Suedoises, Vols. 22-26, 1880-4.
- STONYHURST, COLLEGE OBSERVATORY.—Results of Meteorological and Magnetical Observations, 1888.
- ST. PETERSBURG, PHYSIKALISCHES CENTRAL-OBSERVATORIUM.—Annalen, 1887, Part II.
- SYDNEY, GOVERNMENT OBSERVATORY.—Daily Weather Charts of Australia and New Zealand, April 1 to Oct. 31, 1889.—Results of Meteorological Observations made in New South Wales during 1886 and 1887.—Results of Rain, River, and Evaporation Observations made in New South Wales during 1887 and 1888.
- SYDNEY, ROYAL SOCIETY OF NEW SOUTH WALES.—Journal and Proceedings, Vol. XXII. Part 2.
- TASMANIA, ROYAL SOCIETY.—Papers and Proceedings, 1888.
- TOKIO, IMPERIAL METEOROLOGICAL OBSERVATORY.—Annual Meteorological Report, 1886, Part 1, and 1887, Part 1.—Report of the Meteorological Observations in the Empire of Japan for the years 1883 to 1885.
- TOKIO, IMPERIAL UNIVERSITY OF JAPAN.—Calendar for the year 1888-89.
- TORONTO, METEOROLOGICAL OFFICE.—Monthly Weather Review, Aug. 1884, Aug. and Sept. 1887, and Oct. 1888 to Sept. 1889.—Report on the Meteorological Service of the Dominion of Canada, 1878 and 1879.—Toronto General Meteorological Register for the years 1887 and 1888.
- TRIESTE, OBSERVATORIO MARITTIMO.—Rapporto Annuale, 1886.
- TUCUMAN, OFICINA QUÍMICA.—Boletín, Tomo I. Entrega 6 to Tomo II. Entrega 2.
- TURIN, SOCIETÀ METEOROLOGICA ITALIANA.—Annuario Meteorologico Italiano, 1889 and 1890.—Bollettino Mensuale pubblicato per cura dell' Osservatorio Centrale del Real Collegio Carlo Alberto in Moncalieri, Vol. VIII. No. 12 to Vol. IX. No. 11.
- UPSALA, OBSERVATOIRE MÉTÉOROLOGIQUE DE L'UNIVERSITÉ.—Bulletin Mensuel, 1888.
- UTRECHT, KONINKLIJK NEDERLANDSEH METEOROLOGISCH INSTITUUT.—Nederlandsch Meteorologisch Jaarboek, 1879, Part II. and 1888.—Waarnemingen van Onweders in Nederland, 1888.
- VIENNA, K. K. CENTRALANSTALT FÜR METEOROLOGIE UND ERDMAGNETISMUS.—Beobachtungen, Oct. 1888 to Sept. 1889.—Jahrbuch, 1887.
- VIENNA, ÖSTERREICHISCHE GESELLSCHAFT FÜR METEOROLOGIE.—Meteorologische Zeitschrift, Dec. 1888 to Dec. 1889.
- WASHINGTON, HYDROGRAPHIC OFFICE, U.S. NAVY.—Pilot Chart of the North Atlantic Ocean, Jan. to Dec. 1887, and Dec. 1888 to Dec. 1889.—The Great Storm off the Atlantic Coast of the United States, Mar. 11-14, 1888. By E. Hayden.
- WASHINGTON, SIGNAL OFFICE.—Bibliography of Meteorology, Part I. Temperature.—List of Books and Articles on Climatology and Meteorology in the Library of the Surgeon-General's Office, U.S. Army.—Report on the Proceedings of the United States Expedition to Lady Franklin Bay, Grinnell Land. By Lieut. A. W. Greely, Vols. I. and II.
- WASHINGTON, SMITHSONIAN INSTITUTION.—Annual Report, 1886, Part 1.
- WATFORD, HERTFORDSHIRE NATURAL HISTORY SOCIETY.—Transactions, Vol. V. Pts. 4 and 5.

WELLINGTON REGISTRAR GENERAL'S OFFICE.—Statistics of the Colony of New Zealand, 1887.

WELLINGTON COLLEGE, NATURAL SCIENCE SOCIETY.—Annual Report, 1888.

ZI-KA-WEI, OBSERVATOIRE MAGNÉTIQUE ET MÉTÉOROLOGIQUE.—Bulletin Mensuel, 1887 and 1888.

ZÜRICH, SCHWEIZERISCHE METEOROLOGISCHE CENTRAL-ANSTALT.—Annalen, 1887.

Presented by Individuals.

ABERCROMBY, HON. R.—Seas and Skies in many latitudes.

ANDRÉ, C.—Influence de l'Altitude sur la Température.—Météorologie Lyonnaise, 1883-7.

ÄNGSTRÖM, K.—Beiträge zur Kenntniss der Absorption der Wärmestrahlen durch verschiedenen Bestandtheile der Atmosphäre.—Beobachtungen über die Durchstrahlung von Wärme verschiedener Wellenlänge durch trübe Medien.—Ein Wage zur Bestimmung der stärke magnetischer Felder.—Résumé préliminaire d'une recherche expérimentale sur l'absorption de la chaleur rayonnante par les gaz atmosphériques.—Sur une nouvelle méthode de faire des mesures absolues de la chaleur rayonnante ainsi qu'un instrument pour enregistrer la radiation solaire.

BATEMAN, L. L.—Returns of the Rainfall in the Glasgow, Manchester, Aston, Dewsbury, Halifax, Blackburn, Stockport, Oldham, and Batley Waterworks Districts, 1888.

BAYARD, F. C.—Tables and diagrams illustrating the diurnal range of barometric pressure in the British Isles.

BERTODANO, C. E. de.—Registro del servicio meteorológico en Luzon y costa de China, Jan. to Dec. 1888.

BINYON, J. B.—Rainfall, &c. at Blackrock, near Cork, Dec. 1888 to May, and July to Nov. 1889. (MS.)

BROWN, A., AND WHITELEGGE, DR. B. A.—Meteorological Observations at Nottingham, 1888.—The Meteorology of Nottingham, 1867 to 1888.

BUSHELL, R.—Twenty-five years' rainfall in Wirral, North-west Cheshire.

CAMERON, DR. J. S.—Annual Report of the Medical Officer of Health for Huddersfield, 1888.

CANTONI, PROF. G.—Il lucimetro Bellani e l' Eliografo Inglese.—Istruzioni per l' uso del Lucimetro Bellani.—Osservazioni Lucimetriche.

CARLIER, H.—Observatoire Météorologique de Saint-Martin de Hinx, France; Observations Météorologiques, 1885, 1886, and 1888.

CAWLEY, R.—Meteorological Observations made at Northwich, Cheshire, 1889. (MS.)

CLARK, J. E.—The Natural History Journal and School Reporter, 1889.

COLLADON, PROF. D.—Sur la durée de l'éclair.

COOKE, R.—Meteorological Observations made at Detling, Kent, 1889. (MS.)

COXEN, MRS.—Meteorological Observations made at Bulimba, Queensland, July 1888 to June 1889.

CROVA, PROF. A.—Mesures de l'intensité calorifique des radiations solaires à Montpellier pendant l'année 1876.—Mesure de l'intensité calorifique des radiations solaires et de leur absorption par l'atmosphère terrestre.—Notes sur les observations actinométriques faites pendant l'année 1887 à l'observatoire de la commission météorologique à l'école nationale d'agriculture de Montpellier.—Observations faites à Montpellier avec l'actinomètre enregistreur.—Observations faites au sommet du Mont Ventoux sur l'intensité calorifique de la radiation solaire.—Rapport sur les expériences faites à Montpellier pendant l'année 1881 par la commission des appareils solaires.—Sur la mesure de l'intensité calorifiques et de la transmissibilité des radiations solaires dans les observatoires météorologiques.—Sur la transmissibilité de la radiation solaire par l'atmosphère terrestre.—Sur le mode de répartition de la vapeur d'eau dans l'atmosphère.—Sur l'enregistrement de l'intensité calorifique de la radiation solaire.

CURTIS, H. P.—Blizzards, Cyclones, and Tornadoes. By W. A. Eddy.

DENZA, PADRE F.—I primi cultori italiani dell' aeronautica.—I terremoti di Novembre e di Dicembre 1887 in Italia.—La inclinazione magnetica a Torino e nei dintorni.—Le Valanghe degli inverni 1885 e 1888.

DUNCAN, J. W.—Meteorological Observations taken at Yeovil, Jan. to Nov. 1889. (MS.)

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EGAR, S.—Meteorological Observations taken at Wryde, Northamptonshire, 1889. (MS.)

EGESON, C.—Climatological Charts of Australia, July and Aug. 1889.—Egeson's Weather System.—The daily area of rainfall in New South Wales, Jan. to Oct. 1889.—Weekly Rainfall Maps for New South Wales, May 1 to June 11, 1889.

EXHOLM, N.—Sur la chaleur latente de vaporisation de l'eau et la chaleur spécifique de l'eau liquide

- ELLIOT, DR. G. S.—Meteorological Observations made at Caterham, Surrey, 1889. (MS.)
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- FINEMAN, C. G.—Spejelnefoskopet och des användning vid molnobservationer.
- FOX, H. C.—Strathpeffer Spa. Its Climate and Waters. By Dr. F. Fox.
- FOX, W. L.—Meteorological Tables for West Cornwall and the Scilly Islands, 1888.
- GLEDHILL, G. W.—Meteorological Observations made at High Harrogate, Yorkshire, July to Dec. 1889. (MS.)
- GLYDE, E. E.—Abstract of Meteorological Observations at Babbacombe, Torquay, during 1888.—Meteorological Summaries, Dec. 1888 to Oct. 1889; made at Babbacombe, Torquay.—Seventh Report (second series) of the Committee on the Climate of Devon.
- GREENWOOD, W. N.—Kludonometric Tide Tables for the Lancashire Coast and Bristol Channel, 1890.
- HALL, M.—Jamaica Weather Report, Oct. 1888 to Oct. 1889.
- HALLAM, T.—Meteorological Report, Albert Park, Middlesborough, April to Nov. 1889. (MS.)
- HAMBERG, DR. H. E.—De l'influence des forêts sur le climat de la Suède. III. Humidité de l'air.
- HAMLIN, G.—Meteorological Observations made at Buckfastleigh, Devonshire, Jan. Feb. and Dec. 1889. (MS.)
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- HEWITT, C. E. B.—Wiltshire Rainfall, Oct. 1888 to Oct. 1889.
- HILL, S. A.—On Temperature and Humidity Observations made at Allahabad at various heights above the ground.—The Tornadoes and Hailstorms of April and May 1888, in the Doab and Rohilkhand.
- HOFFERT, DR. H. H.—Intermittent Lightning Flashes.
- HOFFMAN, H.—Phänologische Beobachtungen, 1888.—Ueber den praktischen Werth phänologischer Beobachtungen.
- HOPKINSON, J.—Meteorological Observations at the Grange, St. Albans, 1887-8.—Report on Phenological Phenomena observed in Hertfordshire, 1887-8.—Report on the Rainfall in Hertfordshire, 1887-8.
- HOWLETT, REV. J. A.—Meteorological Observations taken at St. Michael's Hereford, Oct. to Dec. 1889. (MS.)
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- LANCASTER, A.—Notes Biographiques sur J. C. Houzeau.—Le Climat de la Belgique en 1888.
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- MAWLEY, E.—Meteorological Observations taken at Berkhamsted, Dec. 27 1888, to Dec. 19, 1889.—The Rosarian's Year Book, 1889.
- MCCRACKEN, SURGEON-MAJOR J. A.—Meteorological Observations, 1879-89, taken at various places in India, and at Queenstown, Ireland, and Barbados. (MS.)
- MCLANDSBOROUGH, J., and PRESTON, A. E.—The Meteorology of Bradford for 1888.
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- RAGONA, PROF. D.—Domenico Scinà.—Evaporazione Comparata.—Studi sulla comparazione degli anemometri.—Vero Andamento Diurno della Temperatura.
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- SALLE, OTTO.—Das Wetter, 1889.
- SAUSSURE, H. DE.—Coup d'œil sur l'Hydrologie du Mexique.—Observations sur le bourdonnement électrique des Montagnes.
- SCOTT, R. H., F.R.S.—Nota sulle acque sotteranee della città di Napoli. Dell F. Contarino.—Nota sulle registrazioni del pluviografo Richard negli anni 1886 e 1887, della città di Napoli. Dell F. Contarino.
- SEELEY AND CO., MESSRS.—The Ocean of Air. By Agnes Giberne.
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- SYMONS, G. J., F.R.S.—Sunshine.—Symons's British Rainfall, 1888.—Symons's Monthly Meteorological Magazine, 1889.
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- TAYLOR AND FRANCIS, MESSRS.—Taylor's Calendar of the Meetings of the Scientific Bodies of London for 1889-90.
- TEISSERENC DE BORT, L.—Etude sur la synthèse de la répartition des pressions à la surface du globe.
- THE EDITOR.—American Meteorological Journal, Dec. 1888 to Dec. 1889.
- THE EDITOR.—Ciel et Terre, 1889.
- THE EDITOR.—Nature, 1889.
- THE EDITOR.—Telegraphic Journal and Electrical Review, 1889.
- THE EDITORS.—The Observatory, 1889.
- TRIPS, DR. J. W.—Nature's Hygiene. By C. T. Kingzett.—Report on the Sanitary Condition of the Hackney District, 1886 and 1888.
- TYRER, R.—Rainfall in the County of Gloucester, Dec. 1888 to Nov. 1889.—The Meteorology of Cheltenham during 1888.
- VAUGHAN, J. D. W.—Meteorological Observations taken at Suva, Fiji, July 1889.
- WALCOTT, DR. R. B.—Results of Meteorological Observations in Barbadoes, 1847-86.
- WALKER, T.—Meteorological Observations taken at Addington, Surrey, June to Dec. 1889. (MS.)
- WELLS, J. G.—Meteorological Observations made at Burton-on-Trent, Derbyshire, 1889. (MS.)
- WHITAKER, W., F.R.S.—The Geology of the Fenland. By S. B. J. Skertchly, F.G.S. (Meteorological portions only.)
- WILD, DR. H.—Normaler Gang und Störungen der erdmagnetischen Declination.—Ueber Assmann's neue Methode zur Ermittlung der wahren Lufttemperatur.
- WOLKOF, PROF. A.—Der Einfluss einer Schneedecke auf Boden, Klima und Wetter.
- WOOD, T. H.—Meteorological Observations made at Gwernyfed Park, Brecknockshire, 1889. (MS.)

WOSNIESSENSKI, A.—Ueber die Erdbeben in und um Wernyj im Jahre 1887 und ihre Beziehung zu meteorologischen Vorgängen.

YOUNG, PROF. C. A.—A Text Book of general Astronomy.

ZUVICICH, PROF. A. M.—Program kralj nauticke skole u Bakru, 1887-9.

APPENDIX VI.

REPORTS OF OBSERVATORIES, &c.

THE METEOROLOGICAL OFFICE.—Lieut.-Gen. R. Strachey, R.E., C.S.I., F.R.S., Chairman of the Council; Robert H. Scott, M.A., F.R.S., Secretary; Nav.-Lieut. C. W. Baillie, F.R.A.S., Marine Superintendent.

MARINE METEOROLOGY.—*Current Charts for all Oceans.*—The extraction of data for these charts has made steady progress. All the information contained in the 7,800 logs in the office has been transferred to the charts, and the Remark Books of H.M. Ships are now under examination. Some 800 of these, covering about three years, have already been dealt with.

The Meteorology of the Red Sea, and also of Cape Guardafui.—The monthly charts for these two areas, closely adjacent to each other, are almost ready for the engraver. Those of the Red Sea only require the insertion of generalised current arrows. Those for Cape Guardafui are as complete as the amount of information available will allow.

The Aden Cyclone Charts.—These are now complete and in the engraver's hands. They consist of daily charts for the period of six weeks, covering the duration of the storm and the conditions which preceded and succeeded it respectively.

The Cyclone Track Charts of the South Indian Ocean.—These charts were originally submitted by Dr. Meldrum to the British Association, and subsequently handed over by him to the Meteorological Council, who directed that the information, originally in the form of yearly charts, should be rearranged in order to obtain monthly charts. This has been carried out, and the charts have gone to press. There are nine of them, the cyclones only appearing in ten months, and being so rare in June and July that the information for the two months is given on one chart. Dr. Meldrum's original yearly charts will also be reproduced.

The Charts of Barometrical Pressure for all Oceans.—Two supplementary charts have been issued, one showing the mean barometrical pressure throughout the year, and the others indicating the extent of range of irregular fluctuations. The information contained in this latter chart presents us with some features of considerable interest.

The Meteorology of the South Sea.—The next region to be discussed by the office, and on which work a good commencement has been made, is that lying between Long. 40° and 180° E, and to the Southward of Lat. 35°. This comprises the track from the Cape of Good Hope to New Zealand.

WEATHER TELEGRAPHY.—No change of great importance has been made in this department. *The Weekly Weather Report* has been further enlarged by the addition of monthly supplements, which have taken the place of the Monthly Weather Report.

The Fishery Barometer Inspection has been continued, and comparatively few stations remain unvisited.

LAND METEOROLOGY OF THE BRITISH ISLES.—*The Quarterly Weather Report* for 1886 is in hand, and Part I. has appeared. *The Hourly Readings* for 1886 have been published. This latter volume will in future be materially altered, and instead of its containing the actual hourly measurements of the curves, &c., the hourly means of the different elements for 5-day and monthly periods will be printed. The wind will be given according to 4 components.

The Harmonic Analysis of the barograms for the 12 years ending 1882 has been completed, and the work is now being checked.

The volume of *Observations from Stations of the Second Order* for the year 1885 has appeared. That for 1886 is in the press. It will not be so large as its predecessors, as the number of stations from which the returns are published in detail has been reduced.

The printing of the *Observations from the Foreign Stations of the Royal Engineers and Army Medical Department* has now been completed, and the work will be issued about Easter. It forms a thick volume of 260 pages.

The observations from *Sanchez, Samaná Bay, St. Domingo*, made by the late Dr. W. Reid, have now been printed, and the volume will shortly appear.

The tables for the Registrar General, Ireland, have been prepared in the office as usual.—*March 28th, 1890.*

ROYAL OBSERVATORY, GREENWICH.—W. H. M. Christie, M.A., F.R.S., Astronomer Royal; Departmental Superintendent, William Ellis, F.R.A.S.; Assistant, William C. Nash.—The instruments, observations and records made, and methods of reduction employed, during the year 1889 have been the same as in recent years.

The Thomson electrometer for indication of atmospheric electricity continued in an unsatisfactory state until the autumn of the year 1889, when it was readjusted by Mr. White of Glasgow, and again brought into use in the month of October. The scale is now larger than in the original state of the instrument.

In the spring of the year 1889 Mr. W. H. Dines very kindly tested our Robinson anemometer as well as a smaller instrument formerly used, on his whirling machine. These experiments showed that for high velocities the theoretical factor 8, used for converting the movement of the cups into wind velocity, is too large for both instruments, and that the registered velocities are therefore too great, as has been found for other similar instruments.

The publication of the volume for 1887 has been much delayed owing to the work incidental on the preparation of the Ten year Catalogue of 4,059 Stars. At the end of the *Magnetical and Meteorological "Introduction"* there will be found accounts of experiments made on days of extreme heat, bearing on the question of the effect of radiation from the ground and surrounding objects on thermometers. There is (1) a table of readings of the dry bulb and wet bulb thermometers on the ordinary revolving stand, with the circular board fixed below the thermometers, alternately removed and attached; (2) a table of readings of the dry bulb and wet bulb thermometers in the Stevenson screen, with the door (which fronts the white building of the magnetic observatory) alternately open and shut, with corresponding readings of the dry bulb and wet bulb thermometers on the revolving stand; and (3) a table of readings of the dry bulb thermometer of the new thermograph, with certain protecting radiation boards alternately removed and attached. These are followed by a table giving a comparison between results obtained from the old and new thermographs (both for dry bulb and wet bulb) on the days in the year 1886 when they were concurrently used, as well as a table giving, for the year 1886, June, to 1887, May, a comparison of the sunshine results obtained by the old Campbell form of instrument and the Campbell-Stokes modification of the same.

The "*Reduction of Twenty Years' Photographic Records of the Barometer and Dry Bulb and Wet Bulb Thermometers*," published in the year 1878, contained a reduction of the barometer records for the years 1854 to 1878, and of the thermometer records from 1849 to 1868. Commencing with the year 1877 results deduced from the hourly readings of the photographic records for barometer and thermometers have been printed regularly in the annual volumes of *Greenwich Observations*. In an appendix to the 1887 volume tables are given supplying corresponding results for the years 1874 to 1876 for the barometer, and for the years 1869 to 1876 for the thermometers, so that the reduction of the Greenwich Meteorological photographic records is now complete to the present time, commencing with the year 1854 for the barometer, and with the year 1849 for the thermometers.—*February 24th, 1890.*

ROYAL OBSERVATORY, EDINBURGH.—Ralph Copeland, Ph.D., F.R.A.S., Astronomer Royal for Scotland.

During the year 1889 the Meteorological Record at this Observatory has been limited to a single daily reading at 1 p.m. of the barometer and sundry

thermometers, together with the usual notes of wind and weather, including rainfall.

The four rock thermometers, with bulbs at various depths from 8 to 21 feet, have been read with all care every Monday as in former years.

Monthly digests, based on the bi-diurnal observations at eight principal towns in Scotland, and similar quarterly summaries derived from the records at all the fifty-five stations of the Scottish Meteorological Society, are drawn up at the Observatory and supplied to the Registrar-General for Scotland, by whom they are regularly published in the *Monthly and Quarterly Returns of the Births, Deaths and Marriages*. These summaries are supplemented by comparisons with the weather of former years, as well as by notes on current meteorological phenomena of special interest.—*January 17th, 1890.*

THE KEW OBSERVATORY OF THE ROYAL SOCIETY, RICHMOND, SURREY.—
G. M. Whipple, B.Sc., F.R.A.S., Superintendent.

The several self-recording instruments for the continuous registration respectively of atmospheric pressure, temperature, and humidity, wind (direction and velocity), bright sunshine, and rain have been maintained in regular operation throughout the year. The standard eye observations for the control of the automatic records have been duly registered, together with the daily observations in connection with the U.S. Signal Service synchronous system.

The tabulations of the meteorological traces have been regularly made, and these, as well as copies of the eye observations, with notes of weather, cloud and sunshine, have been transmitted to the Meteorological Office.

The readings of the old 100-inch area square rain gauge have been discontinued since February, the new 8-inch Glaisher gauge being now regularly employed, as a check upon the indications of the Beckley self-recording instrument.

The working standard barometer (Newman, 84) of the observatory, which has been in use continuously since the date of its erection about 1851, having become somewhat worn in its mechanism, was dismantled, and the scale and fittings repaired by Messrs. Negretti and Zambra, without interfering with the tube and cistern, which were retained at the Observatory. On its return it was again put together and restored to its old place, and fresh comparisons made with the Welsh absolute standards. These showed that a slight shift had taken place in the position of the zero of the scale, and a new determination of the scale error was made and fresh corrections accordingly adopted. During the period it was under repair the Royal Society's old standard barometer was used in the daily observations.

The barograph and thermograph formerly at work at the Armagh Observatory have been put in thorough repair, and set up in the Verification House awaiting the instructions of the Meteorological Council as to their transmission to the new Observatory under erection at Fort William, Inverness, at the base of Ben Nevis.

Tables of the monthly values of the rainfall and temperature have been regularly sent to the Meteorological Sub-Committee of the Croydon Microscopical and Natural History Club for publication in their *Proceedings*. Detailed information of all thunderstorms observed in the neighbourhood during the year has been forwarded to the Royal Meteorological Society soon after their occurrence.

The Electrograph has been in constant action throughout the year, and comparisons with the portable electrometer made in March, June, and September show the scale value to have remained unchanged.

The Committee have undertaken at the request of the Meteorological Council to make observations with a pair of Violle's actinometers. These consist of two delicate mercurial thermometers encased, the one in a well-blackened hollow metal sphere, the other in the centre of a similar sphere thickly gilded and having a highly polished surface. Being suitably mounted, they are taken out on sunny days, placed side by side in the open air, and exposed to the solar rays, until they attain the equilibrium temperature.

As it was found that a much more suitable site was offered by the roof of the new building for the working of the cloud cameras, the pedestal was removed from the position it formerly occupied and set up on gratings placed on the new

roof, the necessary alterations being effected in the electrical attachments. Opportunity was taken at the same time of replacing, by new wire, about 80 yards of the cable which had become damaged during the building operations. As, however, the question of the most convenient way of utilising the cloud pictures is still under consideration by the Meteorological Council, no photographs have been taken during the past year.

With a view of examining into the accuracy of the graduations of small anemometers or air-meters very much employed in measuring draughts and air-currents in mine-shafts, galleries, and similar places, a whirling apparatus was constructed and set up in the Optical Room, by means of which a number of experiments were made with Lowne's air-meters kindly lent by Mr. Casella, the maker, which afforded satisfactory results. The examination of these air-meters is now included in the list of operations carried on by the Verification Department.

The electrical anemograph, which was sent to Valencia in 1886 for erection on that island, was returned to Kew in a somewhat damaged condition after a lengthened trial in a very exposed situation. Certain defects in its construction which became evident during its stay there have now been corrected, and, after undergoing thorough repair, the instrument has been erected on a suitable staging on the roof of the Observatory, with the intention of submitting it to a comparison with the Beckley anemograph working at the same level about 14 feet due south of it.

In the Verification Department more than 14,000 instruments belonging to one or other of the twenty-eight different classes have undergone examination, and in the rating branch of the Observatory 528 watches have been submitted to the specified test.

A detailed list of all the operations carried on in the verification department, with the fees charged, &c. is in the press, and will shortly be issued in pamphlet form, price 8d.—*January 14th, 1890.*

RADCLIFFE OBSERVATORY, OXFORD.—E. J. Stone, M.A., F.R.S., Radcliffe Observer.—The following is a report on the meteorological work in this Observatory for the year 1889:—

At the beginning of the year a change was made in the reckoning of the meteorological day. It had been usual in previous years to consider the day to run from noon to noon, but the hourly records now begin with the midnight values and end with those at 11 p.m., except the rainfall and anemometrical records, which include the results from midnight to midnight. The thermometers in the Stevenson screen are read at 8 a.m., noon, and 8 p.m. for the Meteorological Office; the solar radiation and terrestrial radiation thermometers are read at 8 p.m.; the Negretti anemometer, the rainfall, and the thermometers on the Tower are read about a quarter-past twelve (0¼ h. p.m.); and the rainfall in the 22 ft. gauge is measured at half-past twelve.

The instruments are in good order and working satisfactorily; readings of the standard instruments are frequently taken during the day, and sometimes through the night, to check the scale of the photographic sheets.

The mean temperature of the air last year was 1°·0 below the average for the last 84 years; the highest temperature was 79°·5 on July 30th, and the lowest was 19°·7 on January 6th and February 12th. There were 1,221 hours of bright sunshine registered during the year.

The eye-readings are reduced to the end of 1889. The *Meteorological Results* for 1886 are partly ready for press.

Dr. Haldane and Mr. M. S. Pembrey have made some interesting experiments, at the Observatory, on the moisture of the air, for a comparison with the results deduced from the dry-bulb and wet-bulb thermometers.

A meeting of the Midland Natural History Societies was held at Oxford on September 28th and 24th, and a considerable number of the members visited the Observatory, which was opened to them in the afternoon of the 24th.—*March 22nd, 1890.*

CAMBRIDGE OBSERVATORY.—Prof. J. C. Adams, F.R.S.—The meteorological work at this Observatory has been carried on by Mr. H. Todd in the same manner as in former years. Daily telegrams and monthly reports are sent to the Meteorological Office.

No change has been made in the instruments, but the anemometer has been recording very badly, and a new one is about to be erected.—*January 14th, 1890.*

Observations on the Motion of Dust, as illustrative of the Circulation of the Atmosphere, and of the development of certain Cloud Forms.

By HON. RALPH ABERCROMBY, F.R.Met.Sec.

[Received August 21st, 1889—Read February 19th, 1890.]

THE following observations have been made during many years past, with the exception of those on Whirlwinds, which were taken on various deserts on the west coast of South America, mostly in 1889, on the Tamarugal Pampa and on the desert of Atacama. The great value of the latter observations seems to be derived from the fact that in those dry districts we can note the forms in which grains of sand or dust of different weights and sizes arrange themselves when disturbed by air blowing in different kinds of ways; and thence deduce conclusions as to how large or small drops of water, or fine snowflakes, or coarse stones of hail, can be built up into certain cloud forms under the influence of gusts, or showers, or squalls of various types.

On any windy day we can see sand or leaves drawn out into streaks along the ground, and on any plain we can also see loose sand or dry snow formed into waves, whose troughs and crests are perpendicular to the direction of the wind. I have not succeeded in my endeavours to determine the conditions under which wind draws dust into lines parallel to itself, or builds the sand into billows at right angles to its own direction; but we see at once a striking analogy to two great types of cloud structure—the hairy or fibrous *cirrus* structure, whose filaments usually move in the direction of their length, and the fleecy *cirro-cumulus* structure, in which the cloud-bars frequently move at right angles to their length. The structure of *cirro-cumulus* can be reproduced with marvellous accuracy by giving a gentle oscillatory motion to a cylindrical bucket of water, on the bottom of which a little fine sand of suitable size has been sprinkled. The particles gather themselves up into a series of fleecy bars at right angles to the direction of oscillation, which exactly reproduce the appearance of fleecy clouds. Such conditions of oscillation cannot of course exist in nature; but the experiment shows by analogy that fleecy structure can be derived from the action of a current on a stratum of solid detached particles. When a fluid rubs against a flat solid surface, or

against a flat surface of a fluid different from itself, friction sets up a series of friction rollers, as it were, or vortices with horizontal axes, which gather the sand or snow into lines parallel to themselves.

Under certain conditions wind does not blow a sandy plain into straight waves of sand, but into crescent-shaped heaps of a very singular character, which are called in Peru *médänös*, or sand heaps. The general appearance of these will best be explained by glancing at Fig. 1, which was sketched from nature on the Pampa de Joya, below Arequipa, in Peru. The crescent is 4 to 20 feet high in the centre, and tapers down to nothing at the points of the

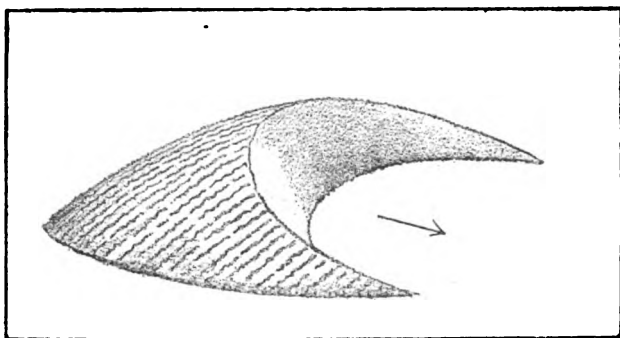


FIG. 1 "MEDANO" OR SAND DRIFT ON THE PAMPA DE JOYA.

horns. The convex side of the whole faces the prevailing wind and presents a low angle of slope, while the inner surface of the crescent is as steep as the sand will lie. The outer surface also, which faces the wind, is transversely furrowed into waves, as shown by wavy lines on the figure, so that there is here a structure on a structure, exactly analogous to what is often seen in cloud forms. The distance from the point of one horn to that of the other will vary perhaps from 20 to 80 feet or more, and the whole advances slowly before the wind, horns first. These *médänös* are developed in great perfection on the Pampa de Joya, where a whole plain, 80 miles across, is covered by these crescents of sand. I never saw a trace of this structure anywhere on the Tamarugal Pampa, above Iquique, or on the Atacama Desert, though the soil in both the latter districts is sufficiently light to be raised into whirlwinds of dust; but I think that the reason is to be found in the character of the sand. The surface of the Pampa de Joya is covered with a sharp, loose volcanic sand mixed with but little dust; while the soil of the other Pampas is more earthy and dusty, besides being more or less compacted with salt; so that the difference in the form and structure of the wind-drifts must be due to difference in the matter to be drifted.

On very rare occasions clouds of the cirro-cumulus type take a somewhat crescent-shaped form, as in certain examples of what are called "mackerel scales," and the ancient Norwegians had a cloud called *Nagelfar*, which was supposed to be made up of parings of nails. I have no observations on the

lie of these crescents relative to the motion of the cloud in which they are, but still I venture to put forward the suggestion that a stratum of cloud, composed of more or less crescent-shaped nubecules, may be formed by the action of wind on a floating layer of snow of some particular size or weight of flake.

We now come to a totally different type of air motion, in which dust is raised spirally, by a whirl round a more or less vertical axis. Those which I observed on the Atacama Desert were all of one type, in which the most violent whirl was on the surface, from which the dust seemed to be projected upwards either like a cloud or as a thin column, but this upper mass seemed to have very little rotation. The appearance at a distance was more like the smoke rising and diffusing into a thick mass above a small fire; rather than like the cylinders of whirling dust which have often been figured. Fig. 2 (A) represents the general impression of one of these whirlwinds, though the top of the sketch exaggerates the amount of rotation in the upper part of the whirl.

In another common variety, a small, intense whirl on the surface, seemed to puff a thin narrow column of dust high into the air, with very little appearance of rotation: see Fig. 2 (B).



FIG 2 TYPICAL DUST WHIRLS. TAMARUGAL PAMPA.

I was unable to determine whether the direction of rotation was always the same; but while endeavouring to make out the cycle of the whole circulatory system, I could sometimes see dust being thrown out, and falling downwards as in Fig. 2 (D). On the whole I think I must have observed nearly 100 whirlwinds, and in every case the central motion was upwards; but I should mention that I was informed that there was a district in Chili, somewhere between Atacama and Copiapo,—which I did not visit,—where the whirlwinds were descending. Whether this meant that the vortex of the whirl was really sucking downwards; or whether the idea was that the upward whirl commenced some distance from the ground and was then propagated downwards, I could not ascertain.

What I wish specially to remark is, that the whirls I saw on the Atacama Desert, starting from the surface, are not identical with the upward drawing

whirlwinds, which begin some height above the ground, and are propagated downwards. These latter are the variety of whirl which generates tornadoes and waterspouts: but which kind presents the greatest analogy to cyclones I cannot say.

As to whirlwinds with descending central vortices, though I have never seen one, I am by no means prepared to deny their existence, for many excellent observers have described such eddies.

For instance Mr. S. Elson, Pilot, of Calcutta, has not only described simple dust whirls near the ground of a descending type, but also a waterspout hanging from a cloud 500 or 600 feet above the earth. To him it seemed as if there was an upward whirl outside the black funnel of the spout, and simultaneously an inside down rush. [See *Calcutta Englishman*, September 18th, 1888.] If the spout and the dark cloud were represented by a sleeve hanging down from a jacket, the lining of the sleeve would be the downward current, and the outside cloth of the sleeve the violent uprush.

Dr. Vettin's experiments on smoke explain the mechanism of such an apparently contradictory circulatory system. If a column of air rises in a stationary medium, the fluid rushes in straight, or radially, to the centre, rises there and flows outwards radially above. But if a rotation is imposed on the system, the rarification of the central core seems to increase so much that air is sucked gently downwards from a stratum above the level of the upper outward current, or above the level of disturbance. The descending current seems to turn up sharply near the ground and join the upward outer current. The influence of rotation also turns both the ingoing and outgoing radial currents into spirally ingoing and outgoing streams respectively.

There is a very simple form of air motion which raises dust without any whirling. Any strong, straight blast of wind will raise a cloud of dust like that in Fig. 3, and the origin of the upward motion is very simple. If while a large body of air is in motion a thread of that air happens to move

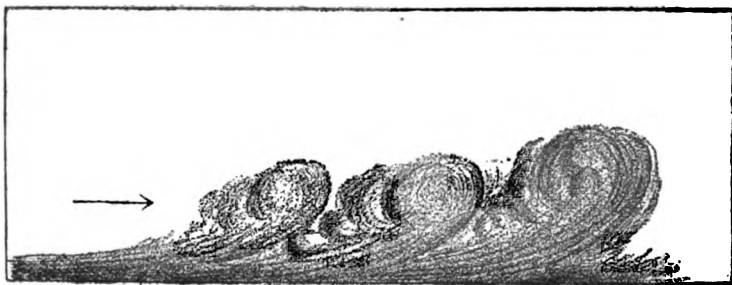


FIG. 3. SIMPLE CONDENSATION OF DUST

quicker than the adjoining portions, the gust so produced will catch up the air in front of itself, and, being pushed on from behind, will be forced to rise and carry some dust up with itself. If the air were laden with vapour instead of with dust, a cloud might be produced by condensation over the gust; and this I take to be the explanation of the simple cumulus cloud, without any

cirrifaction or any complex overlying stratum, which characterises the plain squall, unaccompanied by any shifting of the wind. It also explains what has long seemed puzzling, how cumulus-topped squalls could be formed with a North-west wind in rear of a cyclone, where the general body of air is probably slightly descending; for with the above conception there is no difficulty in the idea of the air rising locally over strong puffs of wind.

Between the simple rising gust and the whirlwind there seem to be various transitional types of air motion, and one which I was enabled to observe reproduces in an extraordinary manner some of the complex features of cloud building over certain kinds of showers or squalls. The dust-cloud represented in Fig. 4 was sketched on the Tamarugal Pampa, and though but a most imperfect delineation of the real thing, still reproduces the important features. A

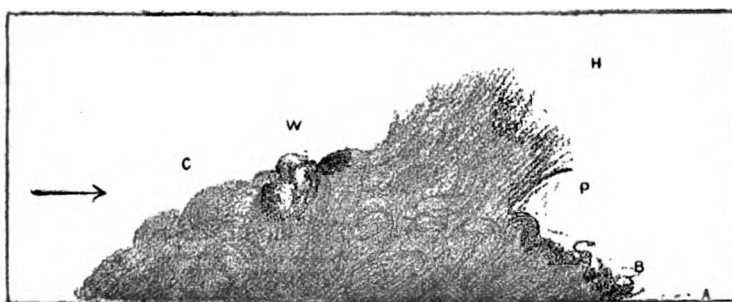


FIG. 4. COMPLICATED DUST WHIRL

dark base projects somewhat forward at B; above the mass again spreads outwards at P, but here the dust, instead of being either shapeless or of a rounded form, has a distinct tendency to be drawn into threads. The rear of the mass C is confused and rounded, and diffuses more gradually into the surrounding air than the front of the dust-cloud. The whole of the lower part of the mass was seething irregularly rather than appearing subject to any definite or distinct rotation, and sometimes a more pronounced rounded-topped column of dust would rise up angrily from the general mass for a few seconds, as at W.

Now compare this with some of the features of cloud-building over certain kinds of showers. In Figs. 5 and 6 are reproduced two diagrams of rain-clouds observed by myself on Lake Titicaca, in Peru. Premising that, on a large scale and with damp air, rain would be precipitated from such an atmospheric uptake as that represented in Fig. 4, the cumuliform lines of cloud C in Figs. 5 and 6 are analogous to the rounded dust forms (Fig. 4 B); while the white cirrifying cloud layers (W) in figs. 5 and 6 are represented by the thin hairy-like dust in Fig. 4 (P). It should be remarked that the clouds in 5 and 6 are viewed facing the direction of motion, while the dust-whirl (Fig. 4) is seen across the line of motion. An observer at A (Fig. 4) would see thin

fibrous dust (P) above a heavy-rolled mass of dust (B), just as in Figs. 5 and 6 I saw a white cirrifying cloud (W) above the dark cumuloform mass (C).

All the observations point to the following view of the origin of squalls—that when the air from general causes is in more or less rapid motion, small eddies of various kinds develop, which constitute the different sort of gusts, showers, squalls or whirlwinds.

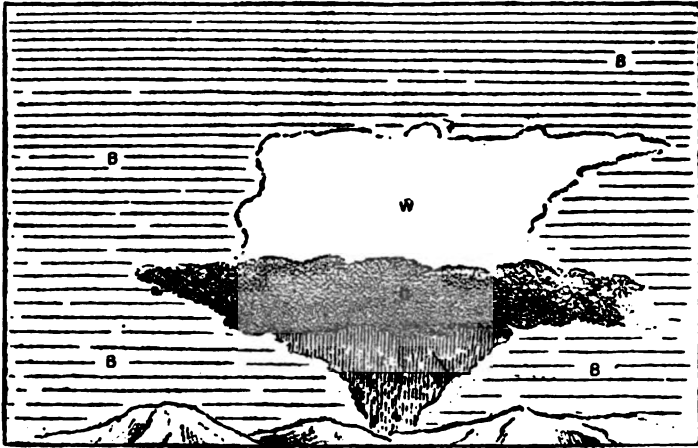


FIG 5. B. BLUE SKY. C. FLAT-TOPPED MASS OF DARK CLOUD, ROUNDED COMPONENTS; R. RAIN; W. WHITE CLOUD, TENDING TO FLATTEN OUT AND TO CIRRIFY.

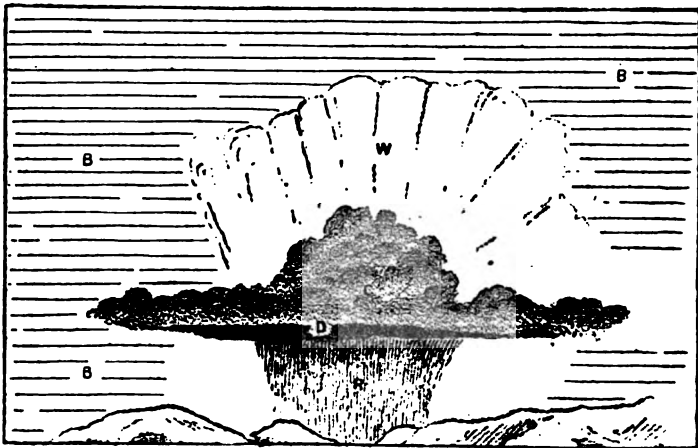


FIG 6 B. BLUE SKY. C. DARK CUMULOFORM CLOUD, FLAT-TOPPED AT EDGES, D. DARK BELT. R. RAIN. W. WHITE CLOUD, TENDING TO FLATTEN AND TO CIRRIFY.

I should like to notice a fact connected with the formation of dust whirls of all kinds, which was brought very forcibly to my notice in many localities. *Whirlwinds never formed till the afternoon wind sprang up.* All the intense insolation of the morning sun—I have recorded the temperature of the sand

at 180° —did not generate whirlwinds so long as the air was calm; and on any day the number of whirlwinds was about in proportion to the strength of the wind. I think this is very important in view of the numerous theories of whirlwinds, tornadoes and cyclones which have been propounded to explain these phenomena by reference to the rise of heated currents simply, without any reference to the general motion of the surrounding medium. The most intense heating, without sufficient wind, never gives rise to more than an intense rippling motion of the air, through which objects look wavy and indistinct, and never of itself induces whirlwinds.

The results of this paper may be summarised as follows:—

Wind sometimes blows dust into streaks or lines, which are analogous to fibrous or hairy cirrus clouds; sometimes into transverse ridges and furrows, like solid waves, which are analogous to certain kinds of fleecy cirro-cumulus cloud; sometimes into crescent-shaped heaps with their convex side to the wind, which are perhaps analogous to a rare cloud form called "mackerel scales;" sometimes into whirlwinds, of at least two, if not of three varieties, all of which present some analogies to atmospheric cyclones; sometimes into simple rising clouds, without any rotation, which are analogous to simple cumulus-topped squalls; and sometimes into forms intermediate between the whirlwind and the simple rising cloud, some of which reproduce in a remarkable manner the combination of rounded, flat, and hairy clouds that are built up over certain types of squalls and showers.

It is specially noted that excessive heating of the soil alone does not generate whirlwinds; but that they require a certain amount of wind from other causes to be moving at the time.

The general conclusion is, that when the air is in more or less rapid motion from cyclonic or other causes, small eddies of various kinds form themselves, and that they develop the different sorts of gusts, showers, squalls and whirlwinds.

DISCUSSION.

Mr. BLANFORD said that he did not quite follow Mr. Abercomby's analogy between the formation of sand-hills and of cumulus clouds. Fig. 1 represented very well what he had frequently seen on the sandy 'churs' of the Ganges (the dry flats in the bed of the river in the dry season), but there the dust was carried much higher than was shown in the illustrations, sometimes attaining an elevation of 500 or 600 feet. Mr. Abercomby had stated that "whirlwinds never formed till the afternoon wind sprang up." He did not question the accuracy of this statement, but as expressed it seemed to imply some confusion of cause and effect. Nothing was more common in India than to see small sand-whirls formed when the air was perfectly calm in hot weather. But where they are numerous, this indicates that convection was beginning to be active, and the ascension of air must be attended with an indraught of air from elsewhere to take the place of that which had ascended. He rather thought that the surface wind was the effect of the upward movement, and that the convection air-whirls and the surface breeze are merely two parts of the same general movement.

Capt. MACLEAR observed that the formation of shoals by currents of water carrying sand, as at river mouths, &c., resembled the *mēdānōs*, or crescent-shaped sand-hills, formed on the South American plains; the definition of the horns depending on the shorter duration of slack water, during which the deposit is

greater and more generally dispersed. As regarded the formation of cumulus cloud he remarked that he had seen this form of cloud produced over the dust and smoke from an Australian bush fire. He did not agree with the author of the paper that dust-whirls were never formed without wind, as he had often witnessed small dust whirls in the Australian bush when the air was perfectly calm. They usually formed quite suddenly on very hot days, and were of sufficient strength to carry hats and light articles up with them. It was, of course, possible that air currents existed higher in the atmosphere, but there was certainly no wind at the ground level.

Mr. HUTCHINS said that in Cape Colony he had seen dust-whirls formed in quite calm weather. These whirls occurred sometimes before noon, though more usually in the afternoon. Another point he had noticed, too, was that the motion of the particles of dust in the whirls was similar to the normal rotation of the wind in the Southern Hemisphere, *i.e.* clockwise and upwards.

Mr. LAWSON said, that in the sand-hills bordering Algoa Bay, at the Cape of Good Hope, there are considerable spaces where sand waves, with a gradual rise on the weather side of the crest and an abrupt fall beyond it, are caused by the prevailing winds at certain seasons. These crests are pretty straight, and frequently as much as half a mile in length, and there are a number of them following in succession; the sand is carried by the wind along the gradual rise to the crest, where it falls into the vacant space in front, filling it up and advancing the edge of the wave. A corresponding mode of transport may be observed in any ordinary ditch, in which there is a small stream of water over a sandy bottom. Regarding the time of occurrence of whirlwinds, he said he had seen one over the sea at Dover at 9 o'clock in the morning. In 1841, in passing through the North-east Trade to Barbadoes, he had often watched the commencement and increase of cumuli, but was unable to account for the peculiar rounded form they assumed until he witnessed the following occurrence. At Barbadoes he was placed in quarantine, in a small vessel, with some cases of measles; while there a soldier washed his belt in a bucket of fresh water, this, with a quantity of pipe-clay suspended in it rendering it quite opaque, he emptied over the side, the sea being perfectly smooth at the time; the pipe-clay water did not mix with the salt water for some time, but gradually subsided, pushing the salt water aside, and presenting the same rounded forms of surface which characterise the cumulus. Here the displacement of one fluid at rest by another took place downwards from the surface; in the case of the cloud the addition of vapour from below causes it to expand upwards, but the appearances, caused by its displacing the dry air around it, are manifestly to be explained in the same manner.

Dr. TRIZE drew attention to a sentence in which Mr. Abercromby said, "Wind sometimes blows dust into streaks or lines, which are analogous to fibrous or hairy cirrus clouds," and said he considered that there were two forms of hairy cirrus clouds, one only of which—the low form—was analogous to the lines of dust. The other form, high up in the atmosphere, does not appear to be produced in any way similarly to the lower form. He thought it desirable that this distinction should be made.

Dr. MARCET remarked that the formation of ripple-marks on a sandy beach at right angles to the direction of the wind was exactly similar to the ripples seen on the surface of a sea or a lake. The formation of ripple-marks by the deposit of particles suspended in water, subjected to a circular movement, and the occurrence of similar striæ on a viscous surface covered with water made to rotate, had been carefully investigated by M. Casimir de Candolle, who had suggested that cirrus clouds might be formed in a similar manner. Dr. Marcet had seen similar ripple-marks on the ice covering the summit of Mont Blanc. He then referred to a remarkable phenomenon described by Prof. Colladon, of Geneva, one of the Honorary Members of the Society, consisting in the upward motion of water particles on the outside of high waterfalls.

Mr. HARRIES wrote giving a reference to Professor Darwin's paper "On the Formation of Ripple-mark" in the *Proceedings of the Royal Society*, Vol. XXXVI. (1888) as bearing in many points on the subject dealt with by Mr. Abercromby. The paper is illustrated by a large number of diagrams, and the works of Mr. Hunt, MM. de Candolle, Forel, and others, in the same direction, are alluded to.

CLOUD NOMENCLATURE.

By CAPT. DAVID WILSON-BARKER, R.N.R., F.R.Met.Soc., F.R.G.S.

[Received December 9th, 1889.—Read February 19th, 1890.]

In the paper on "Cloud Observing," which I had the honour of reading before the Society in 1885,¹ I put forward a dual form of cloud nomenclature as a simple basis on which to found a more elaborate and scientific cloud system; and in fact any cloud classifier must recognise this basis.

In this paper I hope further to elaborate and explain my scheme with the aid of photographs.² No one will deny the necessity there is for more cloud observers, and that the observations should be followed on a more systematic plan than that now pursued. There are several cloud classifications put forward for adoption, some using one form, some another, to the total destruction of the value of cloud observation records in future years. In the majority of cases too much attention is paid to the particular form or shape of a cloud, and not enough to its physical structure and formation; as in former years too much attention was paid to the outward forms of animals, for instance a whale was called a fish because it was shaped like one and swam in the sea, etc. In reconsidering the nomenclature, we must consider not only the outward appearance, but more particularly the formation of clouds.

I by no means wish to say that my plan is the best for getting at what we want, but only place it before the Society as a contribution to the subject, having been a close observer of cloud and general weather phenomena in almost every part of the Ocean World during the last eleven years, under all possible conditions of weather and during all times of the day and night. I quite recognise the difficulty that attaches to any classification, particularly when one comes to deal with what may seem intermediate forms (but this is a common difficulty elsewhere, and we adopt a classification for simplicity), and for obvious reasons it is not only more convenient but almost absolutely necessary that we should have a basis to work on.

Vapour rising in the atmosphere, on condensing, tends to become visible in two ways, either in a globular or heapy form, or in layers or sheets. The former are cumulus (heap clouds), and the latter stratus (sheet clouds); all clouds will belong to either one form or the other, or will be transitory, and these latter we may refer to a sub-type.

It may be as well in the first place to define a cloud, "as vapour which has risen or descended in the atmosphere from a position having a temperature or density greater than the portion of the atmosphere it rises or descends to, which is then unable to retain it in its invisible form, and

¹ *Quarterly Journal*, Vol. XI. p. 119.

² The paper was illustrated by a number of lantern photographs, explaining the Author's proposed division of Cloud forms.

according to the physical state of the place it is attracted to, so will be the form it will assume on becoming condensed."

According to Mr. Aitken¹ no cloud can be formed unless there is a nucleus on which the vapour can condense, and so become visible. Then how are clouds formed at sea? is it possible that there can be dust over the ocean regions? I doubt it, unless in exceptional cases, and even then it seems difficult to imagine that clouds could assume all their varied shapes if they depended upon dust particles to make them become visible. Professor Tyndall aptly calls the minute particles of water vapour, which constitute a cloud, "water-dust." The well-known experiment of Tyndall's, whereby a brilliant cloud may be produced in a tube exhausted of its air by allowing humid air to enter suddenly, would certainly seem to disprove the dust-forming theory.

Before proceeding further it may not be out of place to give, in a few words, a history of cloud-nomenclature. Lamarck first in 1801 classified clouds, then in 1808 Luke Howard gave them seven names, viz., *cirrus*, *cirro-cumulus*, and *cirro-stratus* for high clouds, *cumulus*, *cumulo-stratus*, *stratus*, and *nimbus* for low clouds. This nomenclature is that practically used at present, and I have adopted it in describing my photographs; but however excellent it may have been at the time proposed, it does not come up to our present knowledge, and it is, therefore, desirable that steps should be taken to make some change in this matter.

Of all workers in this direction none have done more than the Rev. W. Clement Ley, and all cloud observers look forward to a monograph on this subject from him. This scientific division of the upper clouds is well known, but I think beginners would have some difficulty in learning the different forms unless first prepared in some way for it; the simple division here proposed would meet this difficulty. Besides Clement Ley, the Hon. Ralph Abercromby has proposed a system² embracing ten varieties, and nine sub-varieties; these are more or less modifications of Luke Howard's forms. Other well-known workers in this field are Poëy, Loomis, A. Mühry, Fitz-Roy, Mohn, Hildebrandsson, Weilbach, and others. Poëy has treated the clouds more fully than anyone since Luke Howard, and his book is well illustrated, though the pictures are sometimes rather fanciful and shaky in perspective. The great fault in all proposed classifications is that they do not meet either requirement, they are not simple enough for beginners, or complete enough—with the exception of Mr. Ley's—for skilled observers.

Cumulus may be defined as the cloud of the lower atmosphere, for although its tops reach great altitudes, yet its first appearance is in the lower regions of the atmosphere; it is also the variety of cloud which is chiefly formed in the rear of cyclonic disturbances, and may generally be considered to denote a state of disturbance—local or general—in the atmosphere. Frequently on the top of cumulus, increasing in size, and indicating considerable local

¹ *Transactions Roy. Soc. Edinburgh*, Vol. XXV., and elsewhere.

² *Weather*, by Hon. Ralph Abercromby, p. 119.

disturbance, will be formed little "cloud caps." It should be observed through all these photographs—though appearing under so many different forms and in places differing widely in geographical position—that they have yet a certain definite likeness to one another, and an observer could be quite safe in describing any one of them as a *cumulus*.

Stratus may be defined as the cloud chiefly of the middle and upper atmosphere; for although it frequently forms in the lower regions, yet it is much more common in the upper and middle parts. It is the cloud of fine settled weather, and also of the front portion of cyclonic disturbances. In the former case it appears either in broken patches, or else spreading all over the sky like a cloak, and having the appearance all round of being in lines parallel to the horizon. The sun shining through rifts in this cloud produces the well-known appearance called the "sun drawing water." As we get higher in the atmosphere it forms cirro-cumulus clouds, which clouds have an enormous range in altitude, appearing in the highest regions as the *cirro-granum* of Ley, and in the middle as the well-known mackerel sky; near the horizon it appears in the form of a thin sheet or layer.

Besides these I should like to call attention to a form of this cloud which I can only liken to the scales of a cycloidian fish in shape, and has a very thin texture; this cloud I have met with everywhere, and it invariably precedes or accompanies rainy weather; its motion is always very slow. I have never succeeded in getting a good photograph of it. All the forms of cirro-cumulus are really stratiform clouds. A very high stratus commonly accompanies very unsettled weather; it appears to consist of portions of cumulus (squall) cloud which are torn off and scattered all over the sky, often rising to great altitudes and forming delicate coronæ. It is most common on the fringes of squalls and showers, and during locally unsettled weather. It is a beautiful cloud, assuming the most wonderful and fantastic shapes, sometimes appearing in long strings and hanks, at other times like a lot of feathers, and again in wavelets.

Still higher in the atmosphere we come to the cirrus clouds, which are composed of minute ice crystals. With the true cirrus we include the cirro-stratus; but with this difference, that, while cirrus appears to be formed chiefly by ascending currents, the latter cloud will first appear as a cirrus and then slowly degrade into a cirro-stratus, later on into nimbus. Fig. 2 represents a vertical section of this cloud in the fore part of a cyclonic disturbance, where at A the cirro-stratus appears in lines; between A and B it is reticulated; at B halos become visible and the line structure disappears; and at C rain comes on: the cirro-stratus has then been propagated downwards until it fills the air to great depths and has become a nimbus. Fig. 1 shows the area over which the cirro-stratus is spread in a cyclonic disturbance. In squalls, we frequently have a great extension, in the rear of the squall cumulus, of the cirriform top, producing at times the appearance of a cirro-stratus cloud and even forming halos; it is seldom that there is any extension in front of the advancing squall.

I may here take the opportunity of mentioning a peculiar kind of haze

that at times fills the upper regions of the atmosphere, more especially in the centre of cyclonic disturbances, and in the rainy regions of the Tropics; it seems to be a kind of steamy stratus; but I am unable to account for it in a satisfactory manner.

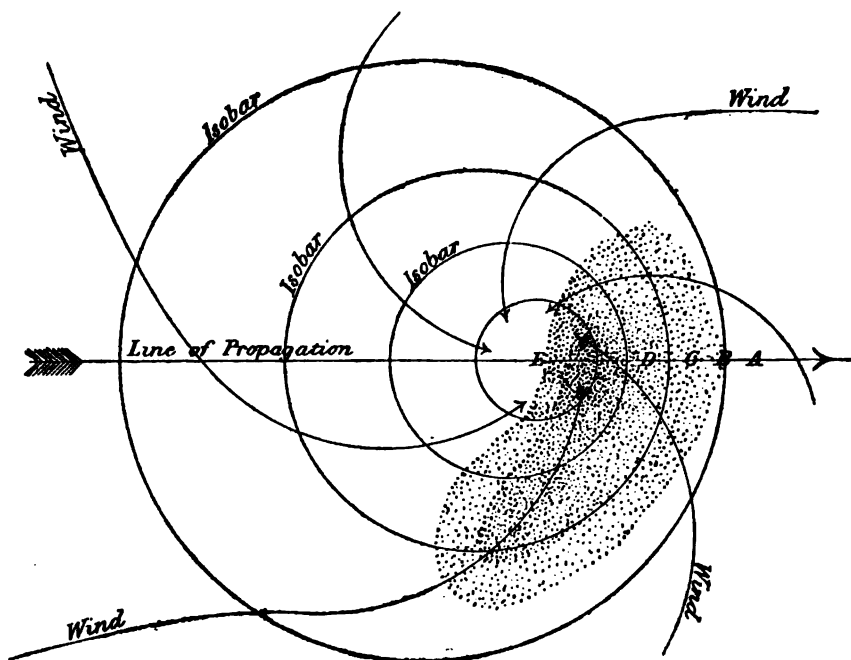


FIG. 1.

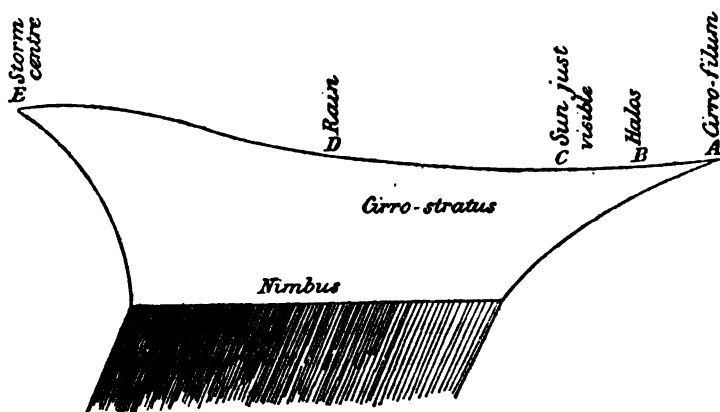


FIG. 2.

The heights to which clouds ascend will vary considerably all over the world, and will depend principally upon the temperature of the district. The actual altitudes are not of so great importance as the relative altitudes to one another.

Once an observer has thoroughly grasped the difference between these primary types, he will soon learn to distinguish the more minute divisions; and I propose "that a primary division of clouds should be arranged, taking the stratus and cumulus as main types, and that a more elaborate and complete division should be made of these two types."

In conclusion, I may state from experience that a good and complete collection of cloud photographs or pictures is indispensable for observers.

DISCUSSION.

Mr. GASTER said that a vast amount of attention had recently been paid to photographs and pictures of clouds taken in various parts of the world, and much good work had been done by Mr. Abercomby, Dr. Hildebrandsson, and the author of the paper now read. But the great difficulty which arose in the question of cloud nomenclature, and which had not yet been met, was to devise such a classification that an observer could so describe the cloud he saw—that there would be no serious difficulty in deciding its form, and whether it belonged to the high, middle, or low level of the atmosphere. He had some time since attempted to prepare such a classification, based upon the old idea of four classes viz. cirriform, cumuliform, stratiform, and composite. With the result, however, he had never been satisfied, and after considering the matter further, he had come to the same conclusion as Captain Wilson-Barker had arrived at, *i.e.* that there were really only two primary forms, *cumulus* and *stratus*. He went on to show that in the upper stratum of the air, nothing but the stratus form is found, that nearer the earth the sheets of stratus grew thicker and their surfaces less well defined, while in the clouds observed near the earth's surface it was often difficult to say which were stratiform and which cumuliform. He entered upon a technical description of the various sub-divisions of the two primary heads, stating the distinguishing features peculiar to each, and concluded by promising to communicate a Paper to the Society, in which he would fully express his ideas on the whole question of cloud nomenclature.

Mr. ROTCH said that the subject of cloud classification had been very fully discussed at the International Meteorological Congress in Paris last September. Various schemes of classification were proposed, but it was the sense of the Congress that the nomenclature of Abercromby and Hildebrandsson, based on the division of Howard, was to be preferred, both on account of its simplicity, which was thought to be of importance for the majority of observers, and also on account of its already wide adoption by meteorologists. In regard to the pictorial representation of cloud types, it was pointed out that the natural colours were very important, but that all attempts hitherto made to reproduce them had been unsuccessful. The want had now been filled by the preparation of a Cloud Atlas by Hildebrandsson and Köppen, which was to be printed by chromolithography in Hamburg, and sold at the price of about twelve shillings a copy.

Mr. DINES wished to inquire whether there was any certainty about the height of clouds. He supposed that most observers formed a fairly correct estimate, but he wished to point out that in the vast majority of cases no possible means existed of knowing whether the estimate was right or wrong. He would explain what he meant by referring to those people who knew the direction of the wind by their feelings. They generally considered their feelings a better guide than a weathercock, but those who preferred the weathercock did not always agree with them as to the direction of the wind. Possibly the cloud observer might be in a similar position, and his estimates of height, if they could be checked, might also at times turn out to be wrong. Probably many persons had now and then seen a cloud, which they had considered the highest, pass across another cloud which they had previously thought to be the lower. He did not wish to imply that the estimates formed were wrong, but only that no means existed of knowing whether they were wrong, and hence he did not altogether agree with taking the height for the basis of cloud specification.

Capt. WILSON-BARKER, in reply, said that he found no more difficulty in determining the relative heights of clouds than in observing their motion. Of

course he did not pretend to be able to determine their actual elevation above the earth with any approach to accuracy; and he thought observers would find no difficulty in this matter, which was of great importance in his proposed primary division of the clouds.

AN OPTICAL FEATURE OF THE LIGHTNING FLASH.

By ERIC STUART BRUCE, M.A., F.R.Met.Soc.

[Received December 1st, 1889.—Read February 19th, 1890.]

In the First Report of the Thunderstorm Committee, which dealt with the photographs of lightning flashes, the Committee called attention to the fact "that there is not the slightest evidence in the photographs of lightning flashes of the angular zig-zag or forked forms commonly seen in pictures."¹ They also referred to the paper that Mr. James Nasmyth communicated to the British Association in 1856, in which Mr. Nasmyth says that a flash of lightning appears to him to be more correctly represented by an intensely crooked line, and he seems to doubt the existence of Artists' Lightning. To these apparently conclusive condemnations of the conventional idea of a lightning flash might be added the words of Mr. Ruskin in *Modern Painters*, when criticising Turner's "Stonehenge." He says:—"The white lightning, not as it is drawn by less observant or less capable painters in zig-zag fortifications, but in its own dreadful irregularities of streaming fire." It is noticeable that these words were written of Turner's picture many years before the publication of Nasmyth's paper.

But on the other side there was the evidence of one's own eyes, and those of many others, as having at times seen a zig-zag flash something very like the depiction of the artist, added to a conviction that in the conventional representation handed down from ancient times there is probably some element of truth.

From the time that the Royal Meteorological Society first exhibited its magnificent collection of photographs of lightning flashes I felt interested in the cause of the discrepancy, and gave the subject some thought and study.

Of one point I felt pretty sure,—that the photographs were a true representation of what exists in Nature (though possibly every kind of flash might not yet have been registered on the photographic plate). I was at first inclined to think that the effect of the angular zig-zag was due to an optical illusion, and I began to search for its cause in that class of phenomena that may be called "eye-sight illusions." While engaged in this search, it all at once occurred to me that I was on the wrong track, and that the explanation would be found not to be an optical illusion, but an optical

¹ *Quarterly Journal*, Vol. XIV. p. 229.

reality—not the flash itself, but the optically projected image of the flash formed on clouds. But why should the projection flash be in angular zig-zags? Because the clouds on which the projection is cast are often of the *cumulus* type, so as to afford an angular surface.

The image of the flash takes the angles of the uneven surface of the clouds. At this point let me make it quite clear that when I speak of zig-zag appearances, I do not mean that irregularity of the line of light that the flash of lightning and spark from an electric machine often displays, but only the long angles of the conventional representation. Having formed this theory in my mind, I proceeded to experiment, and succeeded in reproducing something very like the conventional lightning by casting the projection of a photograph of lightning on model clouds.

I have arranged on the table some model clouds presenting an angular surface.¹ In my lantern I have placed a photographic slide of a flash. It is of that type represented in the Report as “streaming.” I have chosen that type, as it is without the irregularities of the other forms of flashes, being, to quote the description of it in Mr. Abercromby’s report, “a plain, broad, rather smooth, streak of light.” This flash, when projected on to the clouds, is to all appearances no longer a streaming flash, but is broken up into angles, and might be called a zig-zag flash.

Those who have knowledge of the laws of optics might endeavour to account for the projection of the image of a flash of lightning in more ways than one. I will now only point out one of the simplest ways in which it might occur.

Let the incandescent lamp represent a flash of lightning at some distance from the screen of clouds. When the light is flashed on and off, there is the simulation of sheet lightning on the cloud screen; now to transform the *sheet* lightning into *projection* lightning. To do this there must be an addition to the arrangements—a cloud with a small opening in it, somewhere between the flash and the surface of cloud upon which the projection is cast. Let a screen with one small opening represent such a cloud; when this is placed in position and the light flashed on, there is no longer the sheet lightning, but the image of the incandescent carbon—a distorted image as it falls upon the uneven [surface] of clouds. The sides of the horse-shoe of white hot carbon appear to be zig-zagged.

And now to go one step further. If we make another opening in the model cloud, there will be two images formed of the incandescent filament of carbon, and likewise in Nature a multiplication of openings will produce a multiplication of images of flashes. May this not explain the forked appearance so often depicted?

It may be objected that it seems inconceivable how this peculiar type of flash came to be regarded as the only type; for the image is probably not nearly so frequently seen as the flash itself. Perhaps the fact that the image of the lightning flash would not have that intense and dazzling brilliancy of the flash itself may explain this.

¹ These experiments were shown to the Meeting by the aid of the Optical Lantern.

If any brilliant source of light, such as the arc light, be suddenly flashed upon the average human eye, that organ would not recognise the form of the source ; but if the image were flashed upon a screen, any eye would distinguish the image of the white hot carbon points, and so the projection would lose the bewildering brilliancy of the flash, and its distorted form would be impressed upon the mind. The diminution of brilliancy probably also explains that other objection—that no photographic plate seems to have yet registered the zig-zag “ projection ” flash.

DISCUSSION.

Mr. SYMONS said that, in common with all present, he felt much indebted to Mr. Bruce for the pains he had taken in investigating this question and the nicely arranged experiments which he had shown ; but he did not feel convinced that the angular zig-zag flashes, represented in many pictures and engravings as repeatedly turning back at an angle of about 45° , actually existed. He considered that in a lightning flash we saw the actual electric discharge and not its projection on a cloud.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

JANUARY 15TH, 1890.

Ordinary Meeting.

WILLIAM MARCET, M.D., F.R.S., President, in the Chair.

JAMES CLEMINSON, M.Inst.C.E., Villa Albano, Beulah Hill, Upper Norwood, S.E. ;
 WILLIAM JOSEPH HARRISON, Assoc.M.Inst.C.E., 7 Carteret Street, Queen Anne's Gate, S.W. ;
 DAVID ERNEST HUTCHINS, J.P., Knyosa, Cape Colony ;
 FRANCIS JOHN CHARLES MAY, Assoc.M.Inst.C.E., 25 Compton Avenue, Brighton ;
 LINDLEY WILLIAM POYNTER, M.Inst.C.E., 8 Marlborough Terrace, Worthing ;
 THOMAS ROBERTS, Assoc.M.Inst.C.E., Portmadoc, North Wales ;
 ROBERT ROBINSON, M.Inst.C.E., Beechwood, Darlington ;
 JAMES SHAND, M.Inst.C.E., Parkholme, Elm Park Gardens, S.W. ;
 JAMES ARTHUR FORREST DE VINE, The Cliff, Beccles ;
 ALBERT EDWARD WATSON, B.A., 7 St. John's Grove, Croydon ; and
 ROBERT GEORGE YOUNG, Assoc.M.Inst.C.E., County Asylum, Colney Hatch, N.,
 were balloted for and duly elected Fellows of the Society.

JANUARY 15TH, 1890.

Annual General Meeting.

WILLIAM MARCET, M.D., F.R.S., President, in the Chair.

Mr. H. HARRIES and Mr. M. JACKSON were appointed Scutineers of the Ballot for Officers and Council.

Dr. TRIPE read the Report of the Council and the Balance Sheet for the past year. (p. 86.)

It was proposed by the **PRESIDENT**, seconded by **Dr. TRIPE**, and resolved :—
"That the Report of the Council be received and adopted, and printed in the *Quarterly Journal*."

It was proposed by **Mr. BEAUFORT**, seconded by **Capt. MACLEAR**, and resolved :—
"That the best thanks of the Royal Meteorological Society be communicated to the President and Council of the Institution of Civil Engineers for having granted the Society free permission to hold its Meetings in the rooms of the Institution."

It was proposed by **Dr. LAWSON**, seconded by **Mr. TRIPP**, and resolved :—"That the thanks of the Society be given to the Officers and other Members of the Council for their services during the past year."

It was proposed by **Mr. STOKES**, seconded by **Mr. GWILLIAM**, and resolved :—
"That the thanks of the Society be given to the Standing Committees, and to the Auditors, and that the Committees be requested to continue their duties till the next Council Meeting."

The **PRESIDENT** then delivered an Address on "Atmospheric Dust." (p. 78.)

It was proposed by **Mr. BREWIN**, seconded by **Mr. ELLIS**, and resolved :—"That the thanks of the Society be given to the President for his services during the past year, and for his Address, and that he be requested to allow it to be printed in the *Quarterly Journal*."

The Scrutineers declared the following gentlemen to be the Officers and Council for the ensuing year, viz. :—

President.

BALDWIN LATHAM, M.Inst.C.E., F.G.S.

Vice-Presidents.

HENRY FRANCIS BLANFORD, F.R.S., F.G.S.

WILLIAM HENRY DINES, B.A.

CAPT. JOHN PEARSE MACLEAR, R.N.

WILLIAM MARCET, M.D., F.R.S., F.C.S.

Treasurer.

HENRY PERIGAL, F.R.A.S., F.R.M.S.

Trustees.

HON. FRANCIS ALBERT ROLLO RUSSELL, M.A.

STEPHEN WILLIAM SILVER, F.R.G.S.

Secretaries. }

GEORGE JAMES SYMONS, F.R.S.

JOHN WILLIAM TRIPE, M.D., M.R.C.P.Ed.

Foreign Secretary."

ROBERT HENRY SCOTT, M.A., F.R.S., F.G.S.

Council.

FRANCIS CAMPBELL BAYARD, LL.M.

WILLIAM MORRIS BEAUFORT, F.R.A.S., F.R.G.S.

ARTHUR BREWIN.

GEORGE CHATTERTON, M.A., M.Inst.C.E.

ARTHUR WILLIAM CLAYDEN, M.A., F.G.S.

WILLIAM ELLIS, F.R.A.S.

CHARLES HARDING.

RICHARD INWARDS, F.R.A.S.

EDWARD MAWLEY, F.R.H.S.

HENRY SOUTHALL.

WILLIAM BLOMFIELD TRIPP, M.Inst.C.E.

CHARLES THEODORE WILLIAMS, M.A., M.D., F.R.C.P

FEBRUARY 19TH, 1890.

Ordinary Meeting.

WILLIAM MARCET, M.D., F.R.S., Vice-President, in the Chair.

OSWALD BRUCE CUVILJE, F.C.A., 68 Upper Berkeley Street, Portman Square, W ;
 WILLIAM HARPUR, M.Inst.C.E., 197 Severn Road, Cardiff ; and
 HENRY JOHN SPOONER, F.G.S., Assoc.M.Inst.C.E., 809 Regent Street, W.,
 were balloted for and duly elected Fellows of the Society.

The following Papers were read :—

"OBSERVATIONS ON THE MOTION OF DUST, AS ILLUSTRATIVE OF THE CIRCULATION OF THE ATMOSPHERE, AND OF THE DEVELOPMENT OF CERTAIN CLOUD FORMS." By Hon. R. ABERCROMBY, F.R.Met.Soc. (p. 119.)

"CLOUD NOMENCLATURE." By Capt. D. WILSON-BARKER, F.R.Met.Soc. (p. 127.)

"AN OPTICAL FEATURE OF THE LIGHTNING FLASH." By E. S. BRUCE, M.A., F.R.Met.Soc. (p. 182.)

CORRESPONDENCE AND NOTES.

ON THE RAINFALL OF THE RIVIERA.

Having found in M. Teisserenc de Bort's *Quinzaine Météorologique* 1877, page 179, abstracts of the observations made at Nice during the seven years 1870-76, I think that it will be well to convert his rainfall values and insert them in the *Quarterly Journal* as a supplement to my paper, in the last number, page 44.

Yearly total rainfall at Nice by M. Teyssie.

	Ins.		Ins.
1870 ...	34.35	1874 ...	24.37
1871 ...	31.73	1875 ...	17.83
1872 ...	54.49	1876 ...	29.43
1873 ...	31.34		

Mean Yearly Total, 1870-76 ... 31.92 ins.

Mean monthly rainfall at Nice, 1870-76.

	Ins.		Ins.
January ...	3.06	July ...	.61
February ...	1.68	August ...	1.03
March ...	2.88	September ...	1.22
April ...	2.59	October ...	6.03
May ...	1.54	November ...	5.03
June ...	2.19	December ...	4.06

G. J. SYMONS.

BUCHAN'S "REPORT ON ATMOSPHERIC CIRCULATION."

THIS forms one of the "Reports on the Scientific Results of the Voyage of H.M.S. *Challenger* during the years 1873-76." The work is really a re-discussion of all the available information regarding various atmospheric phenomena over the globe. The data are given in nine Tables of the Appendices, of which the more important are the mean diurnal variation of atmospheric pressure at 147 stations, the mean monthly and annual pressure of the atmosphere at 1,866 stations, and a similar table of temperature at 1,620 stations, and the mean monthly and annual direction of the wind at 746 stations.

The Report is divided into two parts, the first dealing with the diurnal

phenomena of meteorology over the ocean, and the second giving a comparative view of the climatology of the globe. The book extends to 842 pages of quarto letterpress, and is illustrated by 2 plates of diagrams and 52 coloured maps, showing the monthly and annual distribution of temperature and pressure of the atmosphere and winds over the globe.

The following is Mr. Buchan's summary of the distribution of the mean atmospheric temperature and pressure for the year:—

"The distribution of the mean annual pressure may be regarded as representing the sum of the influences at work, directly and indirectly, throughout the year, in increasing and diminishing atmospheric pressure and temperature.

"The isothermal of -5° surrounds the north pole, and marks off the region where the annual temperature of the globe falls to the minimum. The regions of highest mean annual temperature, marked off by the isothermal of 85° , occur in Central Africa, in India, the north of Australia and Central America; but, except Central Africa, these areas are very restricted. Temperature is depressed in the greatest degree towards the eastern sides of the land surfaces of the continents as they stretch towards and into the Arctic regions. As regards the ocean, temperatures are low on the eastern coasts of the continents of the northern hemisphere and on the western side of the continents of the southern hemisphere. The effect of the more clouded condition of the atmosphere of intertropical South America as compared with Central Africa is well illustrated by the isothermals of these two extensive regions.

"The most conspicuous example of the influence of ocean currents in raising the temperature is seen in the protrusion northwards of the isothermals over Western Europe, due to the prevailing winds and widespread currents which there pass from lower to higher latitudes. The contrast the temperature of the east coast of America offers to that of Europe is very striking. A similar result, but in a greatly reduced form, is seen on comparing the east of Asia with the west of North America.

"As respects land surfaces of tropical and sub-tropical countries, the highest mean annual temperatures are found in those regions where for a considerable portion of the year the climate is dry and practically rainless. The isothermals of Mexico and Brazil show in a striking manner the influence of dry and wet climates on the distribution of temperature in low latitudes. In this connection the crowding together of the isothermals in Africa and South America about latitude 80° S. is one of the most striking features of these lines.

"The chart of mean annual atmospheric pressure shows two regions of high pressure, the one north and the other south of the equator, which pass completely round the globe as broad belts of high pressure. The belt of high pressure in the southern hemisphere lies parallel to the equator, and is of tolerably uniform breadth throughout, widening, however, in the longitudes of the anticyclonic regions of the Pacific, Atlantic, and Indian Oceans, and of the less pronounced anticyclone of Australia. The belt of high pressure north of the equator has a very irregular outline, and exhibits the greatest differences as regards breadth and inclination to the equator. These irregularities wholly depend on the peculiar distribution of land and water which obtains in the northern hemisphere. The maximum breadth is reached over the continents of Asia and America; and, indeed, the area of high pressure may further be regarded as stretching across the Arctic region from the one continent to the other. The highest mean annual pressure, 30.20 ins., is attained in the anticyclonic region in the North Pacific. On the other hand, the belt of high pressure falls to the minimum in the Pacific immediately to the east of Japan, where it is less than 29.95 ins. It is also to be noted that pressure is nearly equally low in the east of the United States and parts of the Atlantic adjoining. About the same latitudes, both north and south of the equator, pressure is invariably high in the ocean a little to westward of all continents.

"These two belts of high pressure enclose between them the comparatively low pressure of equatorial regions, through the centre of which runs a narrower belt of still lower pressure, towards which the Trade winds on either side blow. This intertropical belt of low pressure exhibits several centres of still lower pressure. The most important and extensive of these includes India, the southern half of Arabia, and a large portion of Central Africa, where pressure falls below 29.80 ins.; and over a considerable part of north-eastern India it falls

under 29.75 ins. Over the larger proportion of the East India Islands pressure is also under 29.80 ins.; and there are besides two small regions near the mouth of the Amazon and near Panama where pressure does not quite reach 29.85 ins.

"Perhaps the most remarkable region of low pressure is in the Antarctic regions, which, remaining low throughout the year, plays the principal rôle in the wind systems bordering on and within the Antarctic Circle, with their heavy snows and rainfall, and in the enormous icebergs which form so striking a feature of the waters of the Southern Ocean. It is probable that over nearly the whole of the Antarctic regions mean pressure is at least less than 29.80 ins.

"In the north polar regions pressure is lower than over the continents, but higher than over the oceans immediately adjoining. In the temperate and Arctic regions there are two strongly marked depressions—the larger covering the northern portion of the Atlantic and adjoining lands, and the other the corresponding portion of the North Pacific, the mean in each falling in the centre below 29.70 ins.

"Now the whole of these areas of low pressure have the common characteristic of an excessive amount of moisture in the atmosphere. The Arctic and Antarctic zones of low pressure, and the equatorial belt of low pressure generally, are all but wholly occasioned by a comparatively large amount of vapour in the atmosphere. But as regards the region of low pressure in Southern Asia in summer, while the eastern half of the depression overspreading the valley of the Ganges has a moist atmosphere and a large rainfall, the western half of it is singularly dry and practically rainless, and its central portion occupies a region where at the time the climate is one of the driest and hottest found at any season anywhere on the globe. Hence, while observation shows the vapour to be the most important and widespread of the disturbing influences at work in the atmosphere, the temperature also plays no inconspicuous part directly in destroying the equilibrium of the atmosphere; from which disturbance result winds, storms, and many other atmospheric changes."

Mr. Buchan concludes as follows:—

"The Isobaric Maps show, in the clearest and most conclusive manner, that the distribution of the pressure of the earth's atmosphere is determined by the geographical distribution of land and water in their relations to the varying heat of the sun through the months of the year; and since the relative pressure determines the direction and force of the prevailing winds, and these in their turn the temperature, moisture, rainfall, and in a very great degree the surface currents of the ocean, it is evident that there is here a principle applicable not merely to the present state of the earth, but also to different distributions of land and water in past times."

THE COMMENCEMENT OF METEOROLOGICAL OBSERVATIONS.

DR. G. HELLMANN, in an article on this subject in the monthly magazine, *Himmel und Erde*, puts the middle of the 17th century as the earliest date for systematic observations.

The earliest instrument was the weathercock. The first man to name the wind after the 4 cardinal points and their combinations was Eginhard, in the time of Charlemagne.

The Greeks erected the Temple of the Winds 100 B.C. with a Triton as vane on top. An actual cock, in metal, as a vane, was put on the church at Brixen in 820. Then followed Hooke's pendulum pressure plate, 1667.

The next instrument was the Hair, or rather Organic, Hygrometer, towards the end of the 15th century, probably due to Leonardo da Vinci. In 1665, Ferdinand II., the Grand Duke of Tuscany, used a "Mostra umidaria," consisting of a conical glass vessel filled with snow or ice. The moisture condensed on the outside of this was caught in a graduated glass measure. This was the first condensing hygrometer.

The Thermometer, as is well known, was invented by Galileo at the very beginning of the 17th century. The Rain-gauge by Padre Castelli about 1639, with the desire of ascertaining how much the surface of Lake Trasymene would be raised by a heavy fall of rain which had overtaken him after an inspection of the lake, then at a very low level.

The last instrument to be mentioned is the Barometer, and that invention of course was due to Torricelli in 1643.

RECENT PUBLICATIONS.

AMERICAN METEOROLOGICAL JOURNAL. A Monthly Review of Meteorology and Medical Climatology. Vol. VI. Nos. 9-11. January-March, 1890. 8vo.

The principal articles are :—The mathematical elements in the estimation of the Signal Service Reports : by W. S. Nichols (6 pp.).—State Tornado Charts : by Lieut. J. P. Finley (11 pp.). The States dealt with are Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut.—Theory of storms, based on Redfield's laws : by M. Faye (21 pp.).—On globular lightning : by Dr. T. C. Mendenhall (10 pp.).—Diminution of temperature with height : by Prof. H. A. Hazen (8 pp.).—The International Meteorological Congress at Paris : by A. L. Rotch (18 pp.). This is an interesting and full account of the proceedings and papers read at the Congress held at Paris, on September 19th to 26th, 1889.—Spectre of the Brocken : by Prof. H. A. Hazen (4 pp.).

CHARTS SHOWING THE NORMAL MONTHLY RAINFALL IN THE UNITED STATES, WITH NOTES AND TABLES. Prepared by H. H. C. DUNWOODY, Capt., Signal Officer. 4to. 1889.

These Charts are based upon observations made at the stations of the Signal Service, Army Posts, &c. during the eighteen years, 1870-1888. The amount of precipitation varies from about 8 ins. in southern California, western Nevada, and western Arizona, to over 100 ins. in the extreme north-western portion of Washington Territory: the annual rainfall at Neah Bay amounting to 105 ins. There are two well-defined systems of precipitation within the limits of the United States; one practically covering that portion of the country east of the Rocky Mountains, and the other extending over the Pacific coast and plateau regions, although the rainfall in the southern plateau region is apparently not wholly within the western system, and the summer rainfalls in Arizona may result from the same causes which produce summer rains in New Mexico and Colorado. The vapour supply of the eastern system is evidently from the Gulf of Mexico and the Atlantic, and the thermal and wind conditions attendant over this area are such as to produce moderate rainfall throughout the year. As a general rule, the annual rainfall in the eastern portion of the United States decreases with the latitude, although the decrease is slight on the immediate coast. It also generally decreases with the distance from the source of supply of vapour. The annual rainfall exceeds 60 ins. on the central Gulf coast, near Cape Hatteras, and in north-east Georgia. It exceeds 50 ins. over the greater portion of the Gulf and south Atlantic, 40 ins. over the middle Atlantic and New England coasts and the greater portion of the Ohio valley, 30 ins. over the states east of the ninety-seventh meridian (excepting Minnesota), and 20 ins. in the region east of the one hundredth meridian. The precipitation occurring within this region is usually attendant upon the passage of areas of barometric depression, and the extent and amount of rainfall accompanying any particular storm, depends largely upon the location and direction of movement of the centre of depression.

BEOBACHTUNGEN DER METEOROLOGISCHEN STATIONEN IM KÖNIGREICH BAYERN. Band. XI. Jahrgang 1889. 4to. 1890.

Contains: Bodentemperaturen an der K. Sternwarte bei München und der Zusammenhang ihrer Schwankungen mit den Witterungsverhältnissen: von Dr. K. Singer (24 pp.). This is a discussion of the observations of earth temperature instituted by Dr. von Lamont at Munich in 1860. The period dealt with is 25 years. The following are the principal results. The general means at the different depths are as follows :—

1·8 metres	=	48°·52 Fahr.
2·5 "	=	48°·48
8·6 "	=	48°·41
4·8 "	=	48°·41
6·0 "	=	48°·81

The mean temperature at the depth of about 1 metre exceeds the mean air temperature by $1^{\circ}\cdot6$, and these figures indicate the distinct influence of the elevation of the station above the sea. The epochs of the extremes and means are as follows:—At the upper station (1·8 metres) min. March 2nd, mean May 21st, max. August 24th, mean November 15th, each stage of descent of 1·2 metres produces a retardation of 21 days for the extremes, and 24 days for the means; and at the lowest station the order of the epochs is nearly exactly reversed, for we have min. May 28rd, mean August 24th max. November 17th, mean February 24th. The earth temperature at 1·8 metres between 1861 and 1889 has never fallen below $85^{\circ}\cdot6$, and never risen above $62^{\circ}\cdot6$; the extremes in the other strata have been successively $89^{\circ}\cdot2$ and $57^{\circ}\cdot2$; $41^{\circ}\cdot0$ and $55^{\circ}\cdot4$; $43^{\circ}\cdot6$ and $58^{\circ}\cdot6$; and $44^{\circ}\cdot6$ and $51^{\circ}\cdot8$. There is not space here to give all the conclusions of the author as to the relation of earth temperatures to weather, and we must refer to the original paper: but we should say that Dr. Singer finds that the amount of moisture exercises a decided influence on the ground temperature, a much heavier rainfall is required to produce effects of this nature in summer when the ground is covered by vegetation than in winter.

METEOROLOGISCHE ZEITSCHRIFT. Redigirt von Dr. J. HANN und Dr. W. KÖPPEN. January-March 1890. 4to.

Contains:—Die meteorologischen Ergebnisse der Lady Franklin Bay Expedition, 1881-83: von Dr. J. Hann (17 pp.). This is an elaborate summary of the scientific results of Gen. Greely's expedition, which are very creditable considering the frightful privations to which the staff were exposed, especially in the last winter.—Zur Frage der Sternenstrahlung: von Dr. J. Maurer (7 pp.). This is an inquiry into the question of what is the temperature of space, and whether any appreciable quantity of heat can reach the earth from the stars. The statement of Pouillet's that the temperature of space is -142°C has been generally accepted. Dr. Maurer gives as his own opinion, supported by Langley and Newcomb, that Pouillet's assertion rests on no solid foundation, and that any heat coming from the stars is quite inappreciable.—Die Theorie des ersten Purpurlichtes: von Dr. J. M. Pernter (10 pp.). This is an examination of the different explanations of the first purple glow, and Dr. Pernter concludes that Kiessling and Riggenbach have been right in attributing it to refraction.—Windstärke und Windgeschwindigkeit auf norwegischen Leuchttower-Stationen: von Dr. H. Mohn (5 pp.). The stations use Wild's pendulum pressure plate anemometer, and when the more recent table of the velocities for each deviation of the plate is used the figures agree well with those given by the Wind Force Committee of the Royal Meteorological Society.—Ueber atmosphärische Bewegungen: von H. von Helmholtz (4 pp.). This deals with the formation of wave motion, where two strata of different density are in immediate contact with each other, as air and water at the sea surface. The author seeks to explain the phenomena of atmospheric disturbances on this principle.—Resultate anemometrischer Beobachtungen auf der ungarischen Tiefebene in Kalocsa: von J. Fényi, S.J. (10 pp.). This is an examination of 6 years' records, in order to see whether Sprung's theory of the variation of wind direction in the daily period was correct for this station. The statement is: "In plains or on table lands the wind has a tendency to shift with watch hands in the forenoon, against them in the afternoon." The general result is satisfactory.

SYMONS'S MONTHLY METEOROLOGICAL MAGAZINE. Nos. 288-290. January-March 1890. 8vo.

Contains among articles: The Eiffel Tower and its use (6 pp.).—Solar halos and parhelia on January 29th (3 pp.).—The Weather Plant (2 pp.).—Rainfall on Ben Nevis during January 1890, by R. C. Mossman.—Remarkably dry air, by Col. M. F. Ward (2 pp.). At Partenkirchen, Bavaria, on January 27th, at 2 p.m. the author recorded by his hair hygrometer the remarkably low relative humidity of 5; the dry and wet bulb thermometer readings also confirming this.—Meteorology in Roumania (3 pp.).—The March frost (2 pp.).—"Areas of rarefaction" or "depressions," by Rev. G. T. Ryves (1 p.).

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Quarterly Journal
OF THE
**ROYAL
METEOROLOGICAL
SOCIETY.**

EDITED BY A
COMMITTEE OF THE COUNCIL.

JULY 1890.

VOL. XVI. No. 75.

LONDON:
EDWARD STANFORD, 26 & 27 COCKSPUR ST., CHARING CROSS, S.W.;
WILLIAMS AND STRAHAN, 7 LAWRENCE LANE, CHEAPSIDE, E.C.

Price Five Shillings.

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Royal Meteorological Society.

ESTABLISHED 1850. INCORPORATED BY ROYAL CHARTER, 1866.

OFFICE :—80 GREAT GEORGE STREET, WESTMINSTER, S.W.

SESSION 1890-91.

ORDINARY MEETINGS at 7 p.m.

NOVEMBER	19	1890.	MARCH	18	1891.
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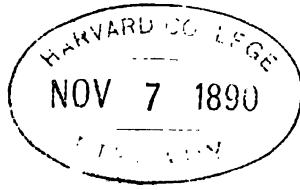
ANNUAL GENERAL MEETING.—JANUARY 21, 1891.

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QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY.

Vol. XVI.

JULY 1890.

No. 75.

A BRIEF NOTICE RESPECTING PHOTOGRAPHY IN RELATION TO METEOROLOGICAL WORK.

By G. M. WHIPPLE, B.Sc., F.R.A.S., F.R.Met.Soc.,
Superintendent of the Kew Observatory of the Royal Society.

[Read March 19th, 1890.]

ALTHOUGH most of the Fellows of the Royal Meteorological Society have been aware, that for many years past photography has been a valued hand-maid to the Meteorologist, in relieving him in a great measure from the labour entailed in taking numerous and frequent observations of thermometers, the barometer, and other necessary instruments, yet comparatively few persons are acquainted with the details of the apparatus or methods employed.

Having prepared for another purpose a set of lantern transparencies of the instruments in use at the Kew Observatory, and at many of the other Meteorological observatories both at home and abroad, the Council of this Society have thought it might offer some interest to the Fellows to exhibit these photographs to this meeting. I have also prepared some notes as to the history of the application of photography to the purpose of continuous

registration, which, I think, may be of importance in throwing light upon the question of priority of the invention, a matter which, so far as I am aware, has not been fully treated of in any text-book of Meteorology.

The prosecution of the study of weather and its changes entails frequent and numerous observations of the various natural phenomena which in the aggregate go to make up what we term "Weather," and which popularly may be described as changes in the various properties of the aerial ocean which surrounds us, and at the bottom of which we live. These phenomena are its temperature; its humidity or extent of dryness, *i.e.* the amount of aqueous vapour it holds in suspension; its motions; its density and also its electrical condition. Variations in its chemical constitution and in the number or nature of the objects accidentally floating in it, such as dust, organic or inorganic, including germs and seeds, although of great interest to the naturalist and sanitarian, are scarcely to be considered as falling within the scope of the science of Meteorology as understood at the present time. It is to be hoped, however, that as we obtain a fuller knowledge of many of the phenomena first mentioned, those later named may come in for more extended notice.

With regard to the question of priority of discovery of photographic registration, I do not wish to be unjust to any person who may be entitled to the credit of being earliest in the field, more especially to any foreigner who may have published suggestions as to the feasibility of this method, but I desire to refer in this paper only to those gentlemen whom I have been able to find as distinctly having removed the invention from the region of conjecture to that of actual *performance*.

In the extreme south-west of England there has existed for 56 years a comparatively small scientific and artistic society—the Royal Cornwall Polytechnic Society, founded by some young ladies in 1838—which publishes annually an 8vo volume of *Proceedings* of about 200 pp.

In 1838 its Secretary, Mr. T. B. Jordan, who was also a mathematical and philosophical instrument maker, in Falmouth, described an instrument for recording by means of photography the variations in the height of the barometer by passing light through the Torricellian vacuum and allowing the top of the mercurial column to arrest the luminous rays in their passage to sensitized paper. Mr. Jordan also devised a recording declination magnetograph, and a self-recording actinometer, all of which instruments with engraved illustrations are described in the Sixth Annual Report of the Polytechnic Society.

The next application of photography, in the order of time, was by Sir Francis Ronalds, at that time Honorary Superintendent of the Kew Observatory, who in 1840 was hard at work on atmospheric electricity. Having constructed an apparatus which he called an electrograph, he obtained a record of the times at which electrical tension caused sparks to pass from a conductor electrified by the air to an earth wire, in the following ingenious manner:—A metal disc covered with sealing-wax was substituted for the hand of a clock, and carried round on its upturned dial, beneath a finger

connected by a wire with a collecting mast. As sparks passed from the conductor on the mast to the ground they heated and softened the sealing-wax on the disc, so that on powdered chalk being shaken over it Lichtenberger's figures were formed, which were retained in the wax when it cooled. Ronalds had these discs placed in front of an ordinary camera, and photographed by Mr. Collen, of Somerset Street, London, a photographer he called in for the purpose. This somewhat roundabout process was soon after modified into one of moving a sensitized photographic plate slowly in front of a pair of electrified gold leaves of a Bohnenberger's electroscope, and recording the amount of their divergence under different electrical conditions.

Next come the simultaneous labours of Brooke and Ronalds, the results of the incentive of grants made by the Royal Society for the successful construction of self-registering instruments. Full accounts of both gentlemen's work will be found in the *Philosophical Transactions* for 1847, and the principal parts of their original apparatus are now to be seen in the Loan Collection of Scientific Apparatus, at the South Kensington Museum.

Since the time of Brooke and Ronalds their magnetographs and meteorographs have undergone many modifications in detail, but not in principle; it is not necessary now to go into these, we shall therefore proceed to other instruments since constructed.

The thermograph and pluviograph are both derived from the barograph; the earth current recorder and Thomson electrograph are both adaptations of Gauss's mirror method, as used by Brooke in the Greenwich magnetograph. The Jordan sunshine recorder, in which the method of producing records is characterised by extreme simplicity, is a descendant of T. B. Jordan's heliograph of 1898. Finally we must mention Roscoe's recording actinometer, and Abney's cloud cameras, as the latest achievements we can consider at present.

I now propose to exhibit on the screen the lantern slides that I have prepared from actual examples of the various instruments enumerated already, which are now in daily work at the Kew Observatory and elsewhere; they are as follows:—

1. Beckley's modification of the Jordan-Ronalds barograph (diagram and instrument).
2. Beckley and Stewart's modification of the Brooke-Airy thermograph (diagram and instrument).
3. Welsh and Beckley's improved Gauss-Brooke magnetographs (diagram and instrument).
 - a. The declination magnetometer.
 - b. Bifilar or horizontal force magnetometer.
 - c. Balance or vertical force magnetometer.
4. Thomson electrograph (diagram and instrument).
5. Jordan's form of sunshine recorder.
6. Whipple's modified Abney's photo-nephograph.

We shall now proceed to consider the various photographic processes which have been employed in connection with the above instruments. To the best

of my belief the process first used for recording on paper (that adopted by Jordan) was Fox Talbot's, and known as the Talbotype, but on account of the sluggishness of the photographic action of this process and its inability to record rapid movements of the magnets, as well as of the supposed irregularity in the traces produced by the warping and shrinkage of paper in the drying and other operations, Ronalds employed the Daguerreotype process for his instruments, which entailed the subsequent copying of the traces for the purpose of preservation by hand on gelatine sheets. The outlines of the curves were traced over by means of an etching point, then ink was rolled over them as in copper-plate printing, and afterwards impressions were worked off for distribution.

The process used by Mr. Brooke, and subsequently by Mr. Glaisher, at the Royal Observatory, Greenwich, was a modified Talbotype process, and is described at length in the introduction to the annual volumes of *Magnetic and Meteorological Observations* made at the Greenwich Observatory.

The Radcliffe Observatory at Oxford, being provided with a Ronalds barograph, early abandoned the use of the Daguerreotype plate in favour of Le Gray's waxed paper process as improved by Mr. Crookes, and these methods were adopted by the Kew Committee, when continuous registration of the magnetic elements was entered upon, at their Observatory, in 1857.

The waxing and ironing of the sheets of Canson's paper was an operation which consumed a great deal of time, but in 1859 this part of the work was much facilitated by Messrs. de la Rue & Co., who undertook the hot-pressing and cutting the paper by means of machinery. The staff at Kew prepared the paper for pressing by arranging it in piles made up of sheets dipped in melted refined white wax, alternating with plain sheets and blotting-paper in a certain order, beforehand. In 1867, the Meteorological Office established their system of seven British Observatories, all working with the Kew pattern instruments and using the same photographic process, and soon after a number of foreign Observatories were also organised, using both magnetographs and meteorographs, all of which came to Kew for their supplies. Messrs. de la Rue found the claims on their good nature too heavy, and were compelled to withdraw their assistance, and so recourse was had to a manufacturer of waxed paper, Mr. John Sanford, who supplied it in considerable quantities, ready prepared for use, until a recent date.

The instability of the silver compound in the sensitized sheets rendered waxed paper extremely subject to change, and any variations in the temperature or humidity of the air might bring about great discoloration of the exposed sheets, frequently causing the partial and occasionally the total loss of the curves. Hence it was a welcome fact to learn that all the requirements of self-recording instruments were met by the use of gelatinized bromide paper. This could be purchased in the market in adequate quantities ready to be wrapped around the cylinders without occupying time in preparatory processes, and could be dealt with subsequently by very easy

methods, not liable to the annoying mischances incidental to development by gallic acid.

Since 1882 Greenwich and Kew, with all its affiliated Observatories, with I think only two exceptions, have entirely abandoned the old or waxed paper for the gelatinized or A.G.B. paper prepared by Messrs. Morgan & Kidd.

This paper, however, has two rather serious drawbacks. The first is the unequal shrinkage of the film and paper, producing distortion in the curves which is considerably greater than that found to exist in the case of waxed paper. The other defect is the curling up of the paper in drying. This, at first, was a serious inconvenience in the operations of measuring and tabulating the curves, but is now of little note, care being taken to avoid unnecessary exposure to either sun-light or heat.

Eastman's paper is, I believe, used similarly in America, and Huntinet's on the Continent, but, so far as I am aware, neither are employed in this country.

We now proceed to consider the sunshine recorder. Mr. James B. Jordan's sunshine recorder records the varying intensities of sunshine by varying the amount of discoloration produced in a paper sensitized by the ferro-cyanide process. A strip of prepared paper is put into a brass box, and the sun's light allowed to pass through a small slit in the side of the box, and fall upon the paper; after the day's exposure, the paper is fixed by immersion in clear water, and we have then upon its surface a blue trace, the intensity of which roughly measures the amount of solar influence upon the earth. As now constructed, a pair of hemi-cylindrical boxes are fixed back to back upon a frame which can be placed parallel to the Equator at the station.

The next and most recently-designed photographic meteorological instrument we would refer to is the photo-nephograph or cloud camera, an apparatus not yet fully developed. Its object is to obtain simultaneous instantaneous photographs of the same cloud from two or three stations situated at a distance from half-a-mile or upwards from each other. These simultaneous pictures are then used for determining the positions of clouds above the surface of the earth, and so obtaining a knowledge of the upper currents of the air, their direction and motion at heights far above those at which anemometers can be placed, and in places where they may be supposed to be unaffected by the irregularities and eddies formed by unevennesses, such as hills and valleys, which modify the contour of the earth's surface.

At Kew, two cameras fitted to theodolites are erected on stands half-a-mile apart, but electrically connected by an underground telegraph wire. Each camera is provided with an adjustable instantaneous shutter, which can be manipulated by an electric current at the will of the directing operator. The *modus operandi* is as follows:—A first points his camera at a selected cloud, and then having instructed the observer at the remote station B, through a telephone, as to the direction in which he should place his instrument, releases both shutters at the same instant of time, so obtaining a pair of pictures in which the stereoscopic effect affords the required data.

The plates exposed are slow gelatine plates, prepared according to a

formula devised by Captain Abney, to whom also most of the details of the arrangement of the instrument are due. After development by pyrogallic acid and fixing, proofs are printed on albumenized or gelatinized paper, from which, subsequently, measurements are made of the photographs, which supply material for the computation of the cloud positions and motions; whilst at the same time valuable information is also given as to structural changes continually in progress in the clouds.

With regard to the utilisation of the photograms given by the recording instruments, suffice it to say that various processes of photographic reproduction by photo-engraving, photo-lithography, &c., have been tried as well as mechanical reproduction by pantographs; but for practical use it has been found best to convert the curves into numbers by methods of tabulation, and then distribute the results to the public as printed columns of figures.

The following is an alphabetical list of the names of the principal Observatories at home and abroad, where photographically recording meteorological or magnetical apparatus is known by the author to be in action at the present date:—

Great Britain and Ireland.—Aberdeen, Falmouth, Glasgow, Greenwich, Kew, Oxford, Stonyhurst, Valencia.

Colonial.—Adelaide, Alipore, Bombay, Hong Kong, Mauritius, Melbourne, Sydney, Toronto.

Foreign.—Batavia, Brussels, Coimbra, San Fernando, Lisbon, Lyons, Madrid, Nantes, Nice, Paris, Perpignan, St. Petersburg, Utrecht, Vienna, Washington, Wilhelmshafen, Zi-ka-Wei.

The lantern slides exhibited have been made, under the author's direction, by Mr. W. Hugo, photographic assistant at the Kew Observatory.

APPLICATION OF PHOTOGRAPHY TO METEOROLOGICAL PHENOMENA.

An Address delivered to the Royal Meteorological Society,
March 19th, 1890.

By WILLIAM MARRIOTT, F.R.Met.Soc.,
ASSISTANT SECRETARY.

MR. WHIPPLE has described the various methods adopted for obtaining meteorological records by means of Photography. My subject, viz. Meteorological Phenomena, has a much wider range, and I hope to show how photography can be most usefully employed for the advancement of meteorological phenomena.

I have made a large number of Lantern Slides from photographs of various meteorological phenomena, which I shall now throw on the screen.

These slides are largely illustrative of the present Exhibition, as they have been mostly taken from objects exhibited in the other room.

CLOUDS.

Slide 1. Typical Cloud Forms, by Hon. R. Abercromby. (*Quarterly Journal*, Vol. XIII. Plate 8.)

Slide 2. Cumulus Cloud, taken by Mons. Paul Garnier at Boulogne-sur-Seine, France.

This slide and Nos. 4 and 5 were taken from a magnificent set of large photographs of clouds sent by Mons. Garnier to the Exhibition. They are the best photographs of clouds that have been seen in this country.

Slide 3. Shower Cumulus Cloud, by Mr. A. W. Clayden.

The measurements were :—

Height of base	...	...	2,500 feet.
Thickness	...	...	4,200 „

A rather heavy shower of cool rain was falling from the cloud.

Slide 4. Cirro-Cumulus Cloud, by Mons. P. Garnier.

Slide 5. Cirrus Cloud, by Mons. P. Garnier.

Slide 6. Cirrus Cloud, by Mr. A. W. Clayden.

Slide 7. The same, taken 10 minutes later.

Slide 8. Cirrus Cloud reflected from the surface of the Lake of Sarnen, August 1888, by Dr. A. Riggenbach.

There has been some difficulty in getting good photographs of the highest forms of cloud, owing to the fact that the blue light of the sky acts with nearly the same actinic energy on the sensitive plate as the white light of the clouds. Dr. Riggenbach, of Basle, in a paper read before this Society in November 1888, said :—"If any plan could be devised for dulling this blue light of the sky while the light of the clouds was left unaffected, the clouds would stand out from the comparatively dark background of the sky in the photographic picture, just as they do in the images formed by our eyes." He explains how the analyser of any polarising apparatus will effect this object; and then goes on to say :—"A still simpler mode of obtaining such cloud-pictures is to use the surface of a lake as a polarising mirror. The best clouds for such a purpose are those at sunrise or sunset, at an altitude of about 87° , and in an azimuth either greater or less than that of the sun by 90° . In the photographs exhibited it will be seen that the clouds are especially clear in the reflection; but the coast lines also come out with unusual distinctness, much clearer than in the direct view, owing to the extinction of the sky light."

LIGHTNING.

On several occasions papers have been read at the Meetings of the Royal Meteorological Society describing various forms of lightning, and special interest has always been attached to the accounts of "ball" or "globular" lightning. This form of lightning appears as a ball or globe of fire, varying in apparent size from a cricket-ball to a football; it moves

slowly—in fact, some people have stated that they have been able to get out of its way—and, as a rule, it finally explodes with great violence. As several persons doubted the existence of ball and some other forms of lightning, the Council considered that much valuable information might be obtained from photographs of flashes of lightning. In response to the Council's appeal in 1887 a large number of such photographs have been sent in to the Society, from which it is evident that lightning does not take the angular zig-zag path so frequently seen in artists' pictures, but pursues a sinuous and very erratic course.

Slide 9. Typical forms of Lightning Flashes. (*Quarterly Journal*, Vol. XIV. Plate 8.)

The Thunderstorm Committee in their Report on these photographs have attempted a classification of the various forms of lightning flashes. The following are some of the most typical forms :—

1. Stream Lightning, or a plain, broad, rather smooth streak of light.
2. Sinuous Lightning, when the flash keeps in some one general direction, but the line is sinuous, bending from side to side in a very irregular manner. This is the commonest type of lightning.
3. Ramified Lightning, in which part of the flash appears to branch off from the main streak, like the fibres from the root of a tree. There is no evidence as to whether these fibres branch off from, or run into, the main flash.
4. Meandering Lightning. Sometimes the flash appears to meander about in the air without any definite course, and forms small irregular loops. The thickness of the same flash may also vary considerably in different parts of its course.
5. Beaded or chapletted Lightning. Sometimes a series of bright beads appear in the general white streak of lightning on the photographic print. These brighter spots occasionally appear to coincide with beads in the meandering type, but often the beads appear without any evident looping of the flash. It is probable that these brighter spots may be points where the flash was moving either directly towards or away from the camera, and thereby giving a somewhat longer exposure to these spots.

Slide 10. Ramified Lightning, by Mr. A. H. Binden, Wakefield, Mass. U.S.A.

Slide 11. Lightning on September 2nd, 1889, by Mr. H. J. Adams, Beckenham.

Slide 12. Lightning at Sea, taken at Hong Kong.

The Committee also described another type, viz. Ribbon Lightning. Some of the photographs show flashes exhibiting more or less of a ribbon-like form. One edge of the ribbon is usually much whiter and firmer than the other. This is produced by optical causes near the edge of the plate, where the pencil of light from the lens falls obliquely and the sensitive film is either beyond or within the focus. The section of the pencil of light is then not circular, but usually consists of a bright point with a nebulous tail, causing a hazy edge to the bright image of the flash. This ribbon character

is not continued all across the plate, but the breadth of the flash and its hazy edgings vary with the distance from the centre of the plate.

Slide 13. Photograph showing Flash with a curtain of light, taken by Mr. E. S. Shepherd, August 17th, 1887.

Some of the photographs showed flashes like a broad band or curtain of light. Several suggestions were made as to the probable cause of this duplication, but the Committee deemed it prudent not to express an opinion on the point. The grand display of Lightning which occurred on June 6th, 1889, afforded an opportunity for photographs to be taken, which have, I think, practically settled this question. Wherever this anomaly occurred, it has been ascertained that in each case the camera was either held in the hand or was not securely fixed.

Slide 14. Photograph showing four parallel flashes of Lightning, June 6th, 1889, by Mr. G. J. Ninnies.

Slide 15. Photograph showing three series of three similar parallel flashes of Lightning which took place while the camera was being swayed to and fro, by Dr. Hoffert, on June 6th, 1889.

The very interesting photographs obtained by Mr. Ninnies, at Balham, and Dr. Hoffert, Ealing, seem to lead to the conclusion that a lightning flash is not instantaneous, but has a much longer duration than has generally been supposed to be the case.

Slide 16. Dark Flash, by Mr. Shepherd.

On one of the photographs taken by Mr. Shepherd, on August 17th, 1887, there was the anomalous appearance of a *dark* flash of lightning. There was a good deal of speculation as to its cause, but the theories advanced were not satisfactory.

Slide 17. Dark Flashes, by Rev. A. Rose.

Three or four photographs showing dark flashes were obtained during the storm on June 6th, 1889, the most notable being those taken by the Rev. A. Rose, at Emanuel College, Cambridge, and by Mr. Clayden, at Tulse Hill.

Slide 18. Photographs of electric sparks explaining the formation of dark images of Lightning flashes, by Mr. A. W. Clayden.

Mr. Clayden has since made a number of experiments in photographing the sparks from an electric machine, which tend to show that the dark flashes are due to photographic reversal. Among the experiments were the following :

1. Sparks photographed in a dark room. No reversal.
2. Plate exposed to diffused daylight after exposure to the sparks. Partial or complete reversal.
3. Small sparks allowed to impress images on the plate, one-half of which was then exposed to gaslight. Complete reversal.
4. Plate exposed to diffused gaslight *after* exposure to the sparks. Reversal.
5. Plate exposed to diffused gaslight *before* exposure to the sparks. No reversal.

Mr. Shelford Bidwell has also made experiments in photographing electric sparks, and has obtained results which confirm Mr. Clayden's explanation of the dark images of lightning flashes.

EFFECTS OF LIGHTNING.

Slide 19. Tree shivered by Lightning at Audley End.

Slide 20. A man's clothes torn off his body by Lightning on June 8th, 1878, while standing under a tree, near Ashford. (*Transactions of the Clinical Society of London*, Vol. XIII. p. 82.)

Slide 21. Clothes of two men who were struck by Lightning at Spaniard's Farm, Hampstead Heath, June 14th, 1888.

Slide 22. Photograph of one of the men injured at Spaniard's Farm, showing the scars on the arm and other parts of the body.

Slide 23. Arm of a boy struck by Lightning at Dunse, Berwickshire, June 9th, 1888, showing arborescent or tree-like markings.

The boy, who was thirteen years of age, had sought shelter with three other boys in a stable when the occurrence took place; he was thrown to the ground and hurt about his face and forehead by the fall. His father, who is a chemist, writes:—

"The motion of the arms was for some while completely paralysed, inasmuch as he was unable, until some considerable time after regaining consciousness, to remove his hands from his pockets, where he had placed them before the accident. There was also in the arms a sensation of numbness and cold, and he fancied that they had been broken at the elbows. Other voluntary movements were at first inaccurate and unsteady. Later, upon his complaining of a burning heat in the arms his coat was removed, and markings of an arborescent character were discovered stretching from below the left elbow to the shoulder, and throwing branches of a less complicated character across the left chest. The marks were of a ramified, tree-like form, and seemed to radiate from two centres, as if the lightning had first struck the arm in two places, and had thence broken over the surrounding skin. Shortly after the accident the boy walked home without assistance, and on his arrival the marks were subjected to a closer inspection. They proved of a red colour, somewhat similar in shape to that of the spots of measles or scarlet fever. The surface of the skin was slightly raised over them, and the superficial heat of the injured arm was greater than that of the rest of the body. For two hours after the stroke they retained their original appearance, remaining to the naked eye at least perfectly unaltered. By 7.30 p.m., eight and a half hours after the accident, they were hardly visible, and at ten o'clock next morning had entirely disappeared."

TORNADOES.

Slide 24. Two views showing the devastation caused by the Tornado at Rochester, Minnesota, U.S.A., on August 21st, 1888.

Slide 25. Ditto.

The great force of the wind in the Tornado was illustrated in a very striking manner by these two views, as one showed a horse impaled by a large branch of a tree; and the other showed pieces of straw driven *end-on* into the bark of trees.

Slide 26. Tornado Cloud taken at Jamestown, Dakota, U.S.A., June 6th, 1887. Two views. The cloud funnel was 12 miles to the north.

Slides 27-30. Damage by the Tornado which passed across the Isle of Wight from Brightstone to Cowes, between 7 and 8 a.m., September 28th, 1876.

An ordinary rapidly revolving whirlwind, looking like a waterspout, or a huge funnel, point downwards, came on the South-west shore of the Isle of Wight, about half-way between Black Gang Chine and the

Needles. The same, or another, passed north-eastwards over Cowes, causing by its updraught great wreckage in the town, carrying off corn, light articles, and even bricks, dropping some on vessels in the Solent, and carrying some north-eastwards on to the mainland south of Titchfield. The damage at Cowes by the whirlwind was estimated at £10,000 or £12,000.

FLOODS.

Slide 31. Railway Bridge between Bransford and Henwick destroyed by the flood on the Teme, May 14th, 1886.

Slide 32. River Severn at Worcester in flood, May 15th, 1886.

Rain commenced falling about noon on Tuesday May 11th over the Midland Counties of England, and continued, but with increasing intensity, till Friday morning; the duration at most places being about 60, and in some places nearly 70, hours. The heaviest fall occurred in Shropshire, where during the three days more than 6 inches fell at several stations, and at Burwarton as much as 7·09 ins. was recorded. At Church Stretton 4·12 ins. fell on the 18th.

The waters of the Severn and Teme continued to rise until 1 a.m. on Saturday, when they reached a point higher than any flood since 1770. About mid-day on Friday 14th, the railway bridge over the Teme between Bransford and Henwick gave way in consequence of the flooding of the river. The centre pier collapsed, and although the railway metals remained, they sank down with the structure, and the line became impassable.

Slide 33. Flood at Rotherham Railway Station, May 15th, 1886.

Slide 34. Flood at Hereford, Midland Railway Station.

Slide 35. Flood at Bristol, March 9th, 1889.

The rainfall was continuous during the 84 hours preceding midnight on March 8th, and during the interval the depth measured reached 2·91 ins. There had been a heavy snow storm throughout Monday, March 4th, which covered the ground to the depth of 6 ins.; and the thaw which occurred on the 5th and 6th served to intensify the effect of the heavy rain which fell on succeeding days. Disastrous floods resulted. At Bristol the loss was estimated at £100,000.

FROST, &c.

Slides 36 and 37. Hardrow Scar Waterfall. Two views: first, Summer flow; second, Winter view, January 25th, 1881.

On January 25th the cone at the bottom was a mass of frozen spray, firm to walk upon, but a stick could be pushed down into it. The cone was about 80 feet high. The upper part was a hollow icicle, semi-transparent, down the centre of which the water could be seen falling and passing into the cone below, which was opaque.

Slide 38. Niagara in winter.

Slides 39, 40 and 41. One view showing the Observatory on Ben Nevis in summer, and two views, in winter, when the Observatory was completely covered in snow and hoar-frost.

Slide 42. Icicles near Aysgarth, Middle Force, February 10th, 1887. By Rev. F. W. Stow.

Slide 43. Thick rime on trees at Lincoln, January 7th, 1889.

Slide 44. Models of Hail stones seven inches in circumference which fell near Montereau, France, on August 15th, 1888. (*Quarterly Journal*, Vol. XV. p. 47.)

THE COLD PERIOD AT THE BEGINNING OF MARCH, 1890.

By CHARLES HARDING, F.R.Met.Soc.

[Read April 16th, 1890.]

THIS paper has been undertaken at the wish of the Council, and the short time which has been at my disposal for its preparation, will, I hope, secure your indulgence, and will sufficiently explain the crude manner in which the somewhat extensive observations have been thrown together.

The discussion is limited to England, as both Ireland and Scotland escaped almost entirely the cold snap which is dealt with in the paper.

The cold was very intense over the whole Continent of Europe during the early days of March.

On March 1st, an anticyclone which had prevailed over the whole of the British Islands for some days suddenly gave way, and a small area of low barometer readings was situated off the East of England, the barometer being below 29·9 ins. This disturbance travelled to the southward and caused a considerable fall of snow in many parts of England, and especially in the South-eastern districts.

After the passage of this disturbance the barometer recovered considerably, and an anticyclonic area embraced the whole of England. This area gradually moved southward, and was situated to the south of England after the 4th.

On the 4th, when the cold was most intense over England, and especially over the southern portion, the air was very still, much of the country being situated between the influence of the anticyclone in the South and the cyclonic circulation in the North and West.

The subdivisions followed by the Meteorological Office have been adhered to, since that grouping collects the observations into reasonably large areas.

The districts dealt with are :—

1. England NE.	12 Stations.
2. England NW.	15 „
3. Midland Counties	27 „
4. England E.	18 „
5. England S.	51 „
6. England SW.	23 „

On March 1st, the minimum temperature fell below the freezing point at every station in the North-east of England; the lowest reading was $24^{\circ}\cdot 8$ at Driffild. The maximum readings were also low, Shields being the only station at which the thermometer exceeded 40° .

In the North-west of England the minima were not quite as low as in the North-eastern district, but the thermometer fell below the freezing point at all except the coast stations.

In the Midland Counties the minima were uniformly below the freezing point except at Wakefield, where the thermometer registered 32° ; the lowest reading in the whole district was $22^{\circ}\cdot 5$ at Cheltenham. The maxima were all below 40° except at Stokesay, Burghill, Hereford and Ross, all situated in the South-western margin of the district, and at most of these stations the thermometer rose to 45° .

In the East of England the minima are shown to be still lower, the thermometer reading 20° at Somerleyton, and at several stations, both on the sea coast and inland, registering 28° and 24° . The maxima were generally only 2° or 8° above the freezing point, except at Hitchin.

In the South of England the minimum ranged from 20° at Brockham to 30° at Totland Bay, Isle of Wight, but the average reading was 25° or 26° . Gosport and Ventnor were the only two places at which the maximum thermometer exceeded 40° .

In the South-west of England the readings were much more variable, but with the exceptions of the stations in the extreme West, the minimum thermometer fell below the freezing point. The maximum thermometer was, however, uniformly above 40° .

On the 2nd, the minimum temperature fell below the freezing point at all stations in the North-east of England except Shields, where it registered 32° only. At Alnwick Castle the reading was 20° . The maximum readings were much lower than on the previous day, and were the lowest of any of the first five days. The highest temperature was 86° , recorded at both Shields and York, whilst at Spurn Head and Lincoln the temperature did not rise above the freezing point throughout the day.

In the North-west of England the minima were lower than on the 1st. At Kirkham the temperature fell to 19° , which was the lowest recorded during the cold spell, but at all other stations the minima occurred on the 8rd or 4th.

In the Midland Counties the thermometer generally fell lower than on the previous day, but the difference was not very great. The lowest reading was $21^{\circ}\cdot 2$ at Buxton, where the elevation is nearly 1,000 ft. At Berkhamsted Mr. Mawley registered $21^{\circ}\cdot 2$, and at Churchstoke the reading was $21^{\circ}\cdot 5$. The maximum temperatures nowhere reached 40° , but with the exception of Harrogate, Buxton, Belper, and Stamford, the thermometer rose above the freezing point during the day.

In the East of England the minimum readings were generally much lower than on the previous day except in the Northern part of the district. The lowest temperature was 18° at Hitchin, and at both Royston and Cambridge the reading was 19° . At several stations the thermometer did not rise above the freezing point throughout the day.

The frost was severe over the whole of the South of England, but the thermometer did not register a lower reading than 20° at any station. The maximum temperature scarcely anywhere exceeded the freezing point by more than 1° or 2° , and at many places it froze all day.

In the South-west of England the minima were not generally much lower than on the 1st; a frost, however, occurred at all stations, but in the Channel Islands and at Scilly the thermometer did not fall below 35° . The maximum readings were, however, lower than on the previous day, and everywhere below 40° except at Weston-super-Mare.

On the 3rd, the cold was more severe at nearly every station in the North-east of England; the lowest temperature was $18^{\circ}6$ at Driffield, but the next lowest was $22^{\circ}5$ at Rounton.

In the North-west of England the minima were also nearly everywhere lower than on the previous day, and at most of the Northern stations, and at Liverpool and Macclesfield, the lowest temperature of the period occurred on this day, and at several of the coast stations the thermometer fell lower than at any time in the previous winter.

In the Midland Counties the minima were everywhere lower than on the 1st or 2nd, except at Churchstoke and Cheltenham, and at all stations in the district the thermometer registered below 25° . At Harrogate, which is the most Northern station, the lowest temperature of the cold spell occurred on this day. The lowest readings were $19^{\circ}5$ at Buxton, 18° at Aspley Guise, and $18^{\circ}8$ at Berkhamsted.

In the East of England the frost was more severe than on the 1st or 2nd, except at Yarmouth and Lowestoft. The lowest readings were 11° at Hillington, $14^{\circ}5$ at Hitchin, and 15° at Cambridge.

In the South of England the temperature was everywhere lower than on the two previous days. At Chatham, Maidstone, Crowborough, Brighton, and Ventnor, the lowest temperature during the cold snap occurred on this day, and the readings were lower than at any time during the previous winter. At Maidstone the thermometer registered 10° , at Chatham 15° , and at Crowborough $15^{\circ}8$. At several stations the maximum during the day did not reach the freezing point; among these were Margate, Hastings, Brighton and Rousdon, whilst at Ventnor the highest reading was only $32^{\circ}4$.

In the South-west of England the minima were everywhere lower than on the 1st or 2nd. At St. David's and Pembroke the lowest reading was registered on this day, and the temperature was lower than at any time during the winter. At Guernsey the maximum during the day was $32^{\circ}9$, and at Jersey 38° .

The Diagram (Fig. 1) for March 3rd shows that the minimum was below the freezing point over the whole of England, as well as at Scilly and the Channel Islands. The coldest areas were in the Eastern parts of England and at Buxton. By far the largest part of England had a temperature between 20° and 25° , whilst there were only a few stations on or near the coasts with readings above 25° .

On the 4th, the temperature in the North-east of England was nearly

everywhere the coldest of the spell, and at some stations the temperature was lower than at any time during the winter. At Driffield the thermometer registered $14^{\circ}5$, and at Lincoln $19^{\circ}8$. The maxima were, however, higher than on the three preceding days, except at Appleby, where the reading on the 1st was nearly 1° warmer.

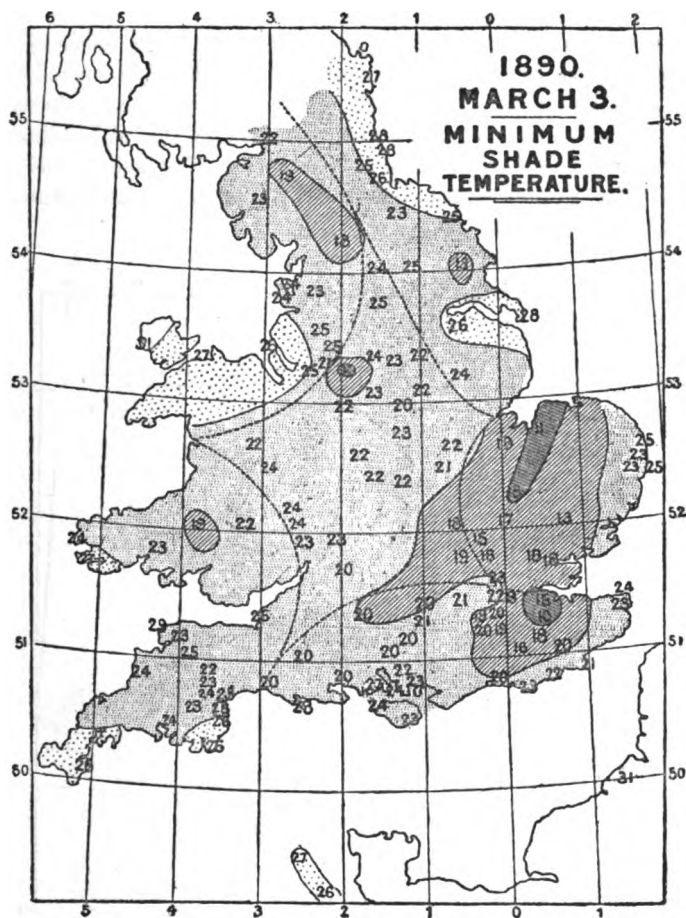


FIG. 1.

In the North-west of England the lowest temperatures for the period were generally observed on the 4th in the Southern part of the district, but a general rise had commenced in the North. The maxima were several degrees warmer than on the preceding days.

In the Midland Counties the minimum for the period occurred on this day except at Harrogate, in the extreme North, which was warmer than the 3rd by $0^{\circ}5$. At very many stations, especially in the South, the temperature was lower than at any time during the winter. The lowest readings were $10^{\circ}9$

at Buxton, 12° at Stamford, $18^{\circ}\cdot8$ at Berkhamsted, $14^{\circ}\cdot9$ at Gloucester, 15° at Cirencester, and $15^{\circ}\cdot2$ at Hereford and Cheltenham. A very marked rise was generally shown in the maximum readings.

In the East of England the minimum on this date was everywhere lower than any recorded during the past winter, at least wherever observations have been made. The lowest readings were 6° at Hillington, $6^{\circ}\cdot8$ at Chelmsford, and $11^{\circ}\cdot2$ at Rothamsted. The minimum was nowhere above 22° , and with the exception of Yarmouth and Lowestoft, nowhere exceeded $15^{\circ}\cdot8$.

In the South of England the minima almost uniformly occurred on this day, and with but one or two exceptions the temperatures were lower than any during the past winter. The lowest readings were $5^{\circ}\cdot4$ at Beddington, 6° at Kenley, $7^{\circ}\cdot8$ at Beckenham, $8^{\circ}\cdot5$ at Addiscombe, 9° at Reigate and Brockham, and 10° at several places in Kent and Surrey, whilst at Greenwich the thermometer fell to $18^{\circ}\cdot1$.

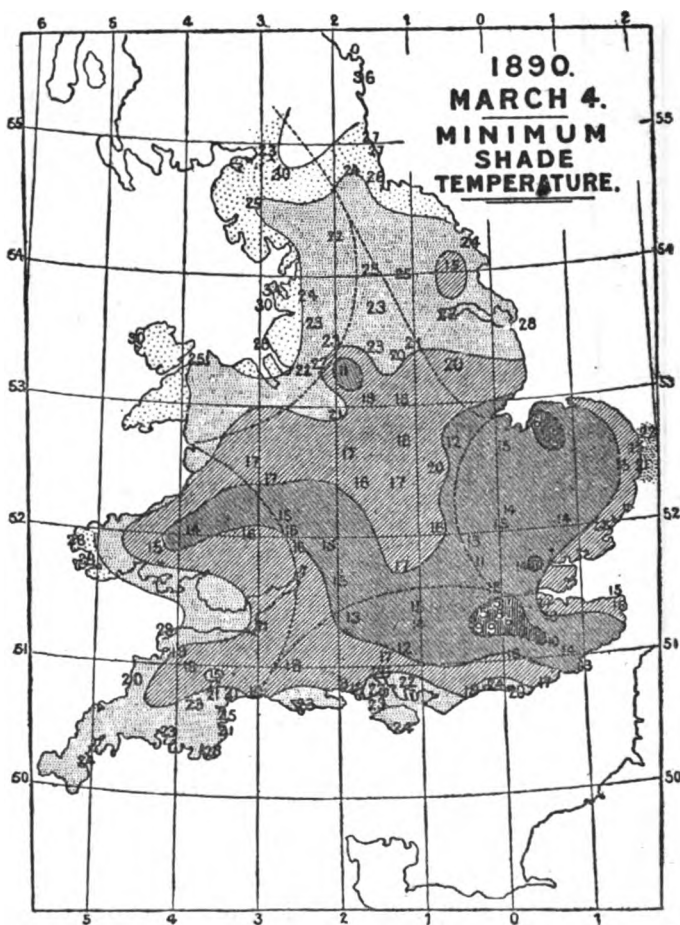


FIG. 2.

In the South-west of England the minima were very low, and wherever the test could be applied the readings were lower than at any time during the winter. The lowest readings were 14° at Llandovery, $14^{\circ}8$ at Cullompton, 15° at Carmarthen, $15^{\circ}5$ at Castle Hill, South Molton, and $15^{\circ}8$ at Gwernyfed Park, whilst in Jersey the thermometer fell to 21° .

The Diagram (Fig. 2) for the 4th shows that the greatest area of cold was situated over Kent and Surrey, whilst equally low readings were recorded at isolated stations in Essex and Norfolk. Temperatures of 15° or below were registered over nearly the whole of the East of England, the Southern Midlands, and in part of the South-western district. The temperatures are seen to be uniformly lower over the Midland, Eastern, Southern, and South-western districts, the readings above 20° being now almost entirely limited to the coast stations, or to the North of England. Some increase of temperature is shown in the North, but Alnwick Castle is the only station over the whole of England (comprising as well Scilly and the Channel Islands) where the minimum reading was above 32° .

On the 5th, a considerable rise of temperature took place over the North-east of England, and frost occurred only at stations in the southern part of the district, whilst the maximum temperature everywhere ranged between 45° and 49° .

In the North-west of England frost only occurred at a very few stations, and the maxima ranged between 45° and 48° .

In the Midland Counties frost was much more general, but very many of the readings entered to the 5th really belong to the 4th, and are due to the practice of reading the thermometers in the morning only. The maxima ranged from 48° at Bawtry to $50^{\circ}8$ at Ross.

In the East of England frost was general but not at all severe, whilst the maxima ranged from $39^{\circ}4$ at Hitchin to 47° at several stations.

In the South of England a slight frost was also experienced, and the maxima were generally between 42° and 52° .

In the South-west of England a similar increase of temperature was shown, the thermometer during the day nearly reaching 50° at many stations.

The following remarks show the localities in which the frost was exceptionally severe, and it is hoped will afford data for comparison with other low temperatures which may be hereafter experienced. The observations for the districts England NE and England NW do not call for any special remark, lower readings being frequently observed at this season of the year.

MIDLAND COUNTIES.

HARROGATE.—Min. $24^{\circ}8$. The thermometer registered 18° on January 8rd.

WAKEFIELD.—Min. $28^{\circ}2$. $19^{\circ}2$ was recorded on January 8rd; which is 4° lower than on March 8rd. Several lower readings observed in March during the last 15 years, and lower winter temperatures very frequent.

HODSOCK.—Min. $19^{\circ}7$. The lowest winter temperature was $19^{\circ}6$ on December 29th. Was lower in March in 5 years during the last 15 years; the lowest being $5^{\circ}8$ on March 10th, 1883; and each year has had a lower winter temperature except 1881-2, and 1883-4. The absolutely lowest reading was $-5^{\circ}8$ on December 7th, 1879.

TABLE I.

SHADE TEMPERATURES OBSERVED FROM MARCH 1ST TO 5TH, 1890.

The Minimum Temperatures printed in italics are the lowest recorded during the Winter of 1889-90.

Stations.	1.		2.		3.		4.		5.		Min.	Date.
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.		
1. England N.E.												
Alnwick Castle.....	37	30	35	20	38	27	45	36	47	39	20	2
Shields	41	30	36	32	38	28	45	27	49	34	27	4
Graham	38.5	30.5	35.5	30.5	35.0	27.5	45.5	26.5	47.5	34.5	26.5	4
Durham	38.9	30.6	34.5	28.5	36.8	26.1	44.6	25.8	48.2	34.6	25.8	4
Ushaw	37.2	28.3	33.0	26.7	35.0	25.0	43.5	24.2	47.9	32.0	24.2	4
Rounton	38.8	28.6	35.2	23.7	36.9	22.5	42.3	25.7	47.1	34.6	22.5	3
Scarborough	36.8	28.5	33.7	30.0	36.4	24.8	38.5	24.3	45.0	36.3	24.3	4
Driffield	37.2	24.5	32.5	28.5	39.8	18.6	40.5	14.5	48.3	35.2	14.5	4
York	40	28	36	28	37	25	44	25	49	29	25	3
Spurn Head	38	30	32	28	35	28	40	28	45	30	28	2
Appleby	38.3	26.8	33.5	27.3	34.8	25.5	37.5	21.8	47.6	32.0	21.8	4
Lincoln	38.0	26.6	31.8	27.2	34.8	23.5	40.4	19.8	47.6	26.7	19.8	4
2. England N.W.												
Scaley	39.7	28.9	37.2	26.4	40.7	21.4	43.7	23.4	47.2	35.1	21.4	3
Newton Reigny	37.8	31.2	34.9	23.5	39.0	19.0	44.0	30.1	45.9	34.9	19.0	3
Seathwaite	36.6	30.3	36.1	25.2	39.6	23.4	44.4	24.9	45.7	36.3	23.4	3
Hawes Junction	32	23	28	18	35	16	39	19	44	28	16	3
Aysgarth	34.8	27.5	31.1	22.5	33.9	17.5	42.0	21.5	47.7	33.8	17.5	3
Kirkham	42	22	37	19	42	24	46	34	47	42	19	2
Stonyhurst	38.6	29.1	34.5	24.8	35.7	22.7	43.3	24.2	44.5	35.4	22.7	3
Blackpool	41.0	32.0	35.0	25.2	37.2	24.0	44.0	29.5	45.8	29.5	24.0	3
Bolton	38.5	28.1	33.0	26.3	32.9	24.6	41.9	22.7	45.2	28.4	22.7	4
Manchester	38.1	27.6	33.3	25.4	33.7	24.7	42.1	23.2	46.2	36.2	23.2	4
Liverpool	40	32	34	27	34	26	44	28	45	32	26	3
Macclesfield	36.1	21.7	31.3	23.7	33.4	21.0	41.1	22.1	44.9	26.6	21.0	3
Northwich	40	29	39	25	37	25	42	22	46	29	22	4
Llandudno	40.0	34.0	36.2	30.0	35.0	26.8	44.0	25.4	46.9	39.8	25.4	4
Holyhead	41	36	37	32	38	31	46	30	48	37	30.0	4
3. Midland Counties.												
Harrogate	37.4	29.8	31.4	25.8	33.9	24.3	42.4	24.8	46.9	33.3	24.3	3
Wakefield	38.7	32.0	33.9	27.3	35.4	24.8	40.7	23.2	47.8	35.0	23.2	4
Bawtry	39	29	39	25	34	22	38	21	43	28	21	4
Hodsock	38.7	28.2	34.0	25.2	36.9	22.5	42.8	19.7	49.6	29.4	19.7	4
Sheffield	37.5	29.3	34.4	26.2	34.3	24.4	40.4	23.1	45.7	31.3	23.1	4
Buxton	32.4	25.6	29.9	21.2	33.1	13.5	36.9	10.9	45.2	19.5	10.9	4
Southwell	39.9	27.5	33.7	25.5	36.5	22.3	42.3	17.2	49.2	27.4	17.2	4
Belper	37.1	26.9	31.4	25.8	34.1	23.1	41.4	19.1	46.8	26.6	19.1	4
Strelley	38.2	25.1	33.1	22.0	35.0	20.0	40.1	18.2	48.9	26.1	18.2	4
Cheadle	35.6	26.0	33.0	24.5	34.0	22.0	38.7	21.4	44.5	34.6	21.4	4
Loughborough	39	28	35	26	39	23	42	18	48	21	18	4
Stamford	39	26	32	23	34	22	40	12	48	25	12	4
Sutton Coldfield	37.5	27.4	34.2	26.0	36.1	21.8	37.1	16.6	45.2	30.0	16.6	4
Churchstoke	39.0	23.0	33.8	21.5	33.8	22.1	42.1	16.5	46.1	38.0	16.5	4
Stokesay	40.7	27.6	34.3	25.6	34.8	24.1	40.6	16.6	45.9	37.1	16.6	4
Uppingham	34.2	25.2	32.7	22.7	34.7	21.0	34.0	19.9	43.6	32.8	19.9	4
Rugby	38	25.4	33	23.6	34.6	21.6	35	17	46.2	33	17	4
Kenilworth	38.8	26.5	32.7	24.3	33.3	22.0	41.8	16.1	47.7	25.4	16.1	4
Aspley Guise	37.4	25.3	37.3	22.9	32.0	18.0	39.8	16.2	47.1	30.4	16.2	4
Burghill	44.6	26.9	34.4	26.8	35.6	23.5	44.4	15.2	48.5	26.5	15.2	4
Hereford	44.6	26.9	34.4	26.8	35.6	23.5	44.4	15.2	48.5	26.5	15.2	4
Ross	45.6	27.4	34.8	26.9	37.5	23.3	44.0	15.8	50.8	26.1	15.8	4
Gloucester .....	..	27.2	..	24.9	..	20.0	..	14.9	..	34.0	14.9	4
Cheltenham	38.6	22.5	34.3	25.2	34.6	22.6	39.2	15.2	46.6	37.3	15.2	4
Oxford	39	26	34	25	35	21	41	17	46	20	17	4
Cirencester	33	23	38	25	33	20	42	15	48	28	15	4
Berkhamsted	35.2	25.3	32.7	21.2	31.2	18.8	33.6	13.8	45.4	32.0	13.8	4

TABLE I.

SHADE TEMPERATURES OBSERVED FROM MARCH 1st to 5th, 1890.—Continued.

The Minimum Temperatures printed in italics are the lowest recorded during the Winter of 1889-90.

Stations.	1.		2.		3.		4.		5.		Min.	Date.
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.		
4. England, E.												
Hillington	34°3	24°6	32°3	24°2	35°3	11°0	35°2	6°0	44°2	31°1	6°0	4
Yarmouth	34	23	33	26	33	25	36	22	44	25	22	4
Somerleyton	34°4	20°1	30°8	23°8	35°0	23°3	38°7	15°1	47°0	29°1	15°1	4
Geldeston	33°6	23°2	33°9	23°2	36°1	23°1	33°9	15°0	43°3	29°0	15°0	4
Lowestoft	35°0	23°8	36°0	24°2	37°0	25°2	34°2	20°9	41°5	29°2	20°9	4
Wryde .....	..	24°8	..	24°0	..	18°8	..	15°3	..	23°8	15°3	4
Cambridge	35	24	31	19	35	15	40	14	47	19	14	4
Sudbury	33	26	32	23	34	18	36	14	43	31	14	4
Royston	35°4	23°5	32°6	18°8	37°9	16°5	41°3	15°3	46°9	34°0	15°3	4
Hitchin	39°0	25°2	35°1	18°4	29°3	14°5	31°0	13°0	39°4	30°4	13°0	4
Rothamsted	35°4	26°0	32°2	21°0	30°6	18°2	35°0	11°2	43°0	30°0	11°2	4
Chelmsford	34°0	23°4	30°9	20°0	33°0	17°9	38°9	6°8	45°8	25°1	6°8	4
Ingatstone	33°7	24°9	30°8	20°9	32°2	17°8	38°4	13°5	45°1	27°5	13°5	4
5. England, S.												
London (Old Street, E.C.)	35°1	27°7	31°9	24°6	34°2	21°5	41°2	20°9	48°2	25°5	20°9	4
Brixton	36	25	32	26	33	23	41	15	46	18	15	4
Kensington	39	24	35	25	32	21	31	16	39	17	16	4
Notting Hill	34°4	25°6	32°2	22°3	32°4	20°9	34°1	18°3	44°3	34°1	18°3	4
Camden Square	35°0	25°8	33°4	23°2	34°5	19°8	40°8	15°6	48°4	25°2	15°6	4
Regent's Park	33°5	24°4	29°8	23°4	31	20°4	40°5	16°5	48°0	31°5	16°5	4
Kew	35°1	27°6	33°1	23°8	31°9	22°4	34°5	18°3	44°3	34°1	18°3	4
West Norwood	35°9	24°1	33°7	24°7	31°8	22°2	33°7	14°8	44°5	29°9	14°8	4
Croydon, Whitgift	36°1	25°2	34°8	24	31	20°5	33	10	41	28	10	4
Addiscombe	36°2	24°9	29°8	23°3	31°1	20°1	40°0	8°5	47°3	23°2	8°5	4
Addington Hills	26°9	22°8	28°7	21°0	38°0	17°5	45°7	14°5	51°0	23°5	14°5	4
Waddon	36°4	24°0	30°0	24°0	30°6	20°0	39°4	17°0	47°6	28°0	17°0	4
Beddington	36°1	23°9	30°0	24°7	31°0	21°0	40°1	5°4	47°7	21°3	5°4	4
Kenley	36°5	25	22	24	22	20	39	6	46	29	6	4
Wallington	36°1	24°3	33°7	23°1	32°2	20°1	36°2	9°8	44°0	30°1	9°8	4
Egham	35°1	26°1	29°5	23°9	30°7	20°8	40°1	19°1	48°1	25°1	19°1	4
Reigate	35	25	33	23	34	19	41	9	44	26	9	4
Brookham	37°3	20°1	30°4	20°5	30°2	19°8	34°9	9°0	47°3	28°4	9°0	4
Dorking	35	25	31	22	31	18	40	14	46	25	14	4
Epsom	35°7	25°0	29°2	23°3	29°8	19°0	32°5	15°3	45°0	30°5	15°3	4
Beckenham	37°7	23°7	35°0	22°5	34°2	18°5	40°5	7°3	47°3	17°3	7°3	4
Greenwich	37°3	25°3	32°6	22°1	33°3	20°1	35°0	13°1	44°0	32°4	13°1	4
Eltham	35	22	30	21	30	18	38	10	43	23	10	4
Chatham	37	25	31	20	32	15	40	24	48	38	15	3
Maidstone	31	26°5	32	20°5	40°5	10	46	19	52	35	10	3
Marlborough	36°4	22°7	32°3	24°8	32°8	19°6	41°6	12°9	46°1	24°9	12°9	4
Reading	34°6	23°0	30°5	23°5	31°2	20°0	38°0	14°8	43°6	29°0	14°8	4
Strathfield Turgiss	36°9	25°9	33°2	25°5	33°0	21°2	42°8	13°8	47°3	24°3	13°8	4
Stowell	35°8	25°2	33°1	26°7	31°0	20°2	41°7	19°1	45°4	27°0	19°1	4
Harestock	37°4	23°0	34°3	23°8	32°3	19°8	36°2	16°6	44°3	30°4	16°6	4
Swarraton	34°6	24°0	30°0	25°2	31°4	19°5	40°5	12°0	45°0	22°0	12°0	4
Cranbrook	36	23	31	24	33	18	37	10	44	16	10	4
Crowborough	35°0	22°8	28°0	23°4	29°8	15°8	31°4	16°2	42°2	27°6	15°8	3
Tenterden	36	24	32	28	34	20	34	14	42	25	14	4
Parkstone	37°7	25°4	36°0	24°8	33°4	20°4	36°7	18°0	47°3	34°0	18°0	4
Margate	35	26°2	34°0	25	31°7	24	33°5	15°2	42°8	26	15°2	4
Ramsgate	34°2	25°2	32°0	28°4	32°9	23°3	38°1	16°4	44°6	24°0	16°4	4
Dungeness	38	22	33	25	32	21	37	13	44	14	13	4
Hastings	39°1	24°5	32°8	28°2	31°3	21°7	40°8	17°4	47°0	26°2	17°4	4
Eastbourne	40°0	28°6	43°6	25°0	33°0	22°6	35°0	20°0	47°0	33°0	20°0	4

TABLE I.

SHADE TEMPERATURES OBSERVED FROM MARCH 1ST TO 5TH, 1890.—*Continued.*The Minimum Temperatures printed in *italics* are the lowest recorded during the Winter of 1889-90.

Stations.	1.		2.		3.		4.		5.		Min.	Date.
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.		
5. England, S.—Continued.												
Brighton	36.9	27.0	31.8	21.1	31.0	20.0	37.8	24.0	43.1	34.0	30.0	3
Worthing	38.7	24.0	32.4	26.3	32.9	21.4	42.4	19.4	44.9	26.5	19.4	4
Portsmouth	36	28	35	29	34	22	42	19	47	29	19	4
Gosport	44.0	25	34.2	27.5	32.6	22.6	41.6	21.6	43.6	25.8	21.6	4
Southampton	39.6	25.3	35.7	25.5	34.9	22.0	37.1	19.5	47.4	32.2	19.5	4
Totland Bay, I.W.	40	30	33	29	33	24	41	23	45	28	23	4
Ventnor, I.W.	40.8	28.6	33.3	28.6	32.4	22.7	42.0	23.7	48.5	27.9	22.7	3
Hurst Castle	40	28	37	29	37	24	42	23	47	25	23	4
Southbourne	38.9	27.4	34.4	28.4	33.0	26.5	44.0	18.4	47.7	27.4	18.4	4
Weymouth	39.5	29.0	34.5	30.0	33.0	23.0	42.5	22.7	48.0	29.0	22.7	4
Bosdon	39.0	26.4	36.5	23.4	30.9	19.6	34.0	18.2	46.8	33.5	18.2	4
6. England, S.W.												
Gwernyled Park	40.2	27.4	35.4	27.3	33.8	21.7	42.6	15.8	46.9	21.4	15.8	4
Llandovery	43	27	36	27	37	19	45	14	49	21	14	4
St. David's	42.7	34.6	37.9	27.8	36.1	24.2	45.0	26.1	48.4	41.1	24.2	3
Carmarthen	44.5	31.8	37.5	25.5	37.5	23.2	42.3	15.0	49.1	34.8	15.0	4
Pembroke	42	33	37	30	35	27	46	28	47	32	27	4
Weston-super-Mare	43.0	33.1	37.8	29.0	35.7	25.2	44.2	21.2	47.8	29.8	21.2	4
Ilfracombe	42.5	35	35.6	32	34.8	29	46	28.6	49.5	33	28.6	4
Arlington	40	28	33	28	32	23	43	19	45	25	19	4
South Molton	40.5	26.5	34.5	28.5	32.0	25.0	44.0	15.5	45.7	23.0	15.5	4
Cullompton	42.2	25.1	35.0	29.1	33.2	21.9	45.8	14.8	49.1	27.9	14.8	4
Bude	42.1	30.6	38.2	31.1	37.0	23.9	46.0	20.1	47.7	36.4	20.1	4
Brampford Speke	41.7	25.9	37.6	29.3	33.8	22.5	43.6	17.2	48.0	26.4	17.2	4
Exeter	42.0	30.8	36.6	30.0	33.6	23.5	44.0	20.5	48.5	25.8	20.5	4
Ashburton	42.7	30.3	37.7	28.9	34.6	22.9	42.7	22.6	49.3	30.0	22.6	4
Sidmouth	41.0	26.8	35.0	29.0	34.6	22.8	44.2	20.5	47.5	30.3	20.5	4
Babbacombe	43.4	28.8	37.1	28.1	32.3	24.7	38.5	24.5	49.6	35.8	24.5	4
Torquay	43	28	37	32	34	26	44	21	50	34	21	4
Prawle Point	43	29	37	30	34	26	43	23	49	27	23	4
Plymouth	42.7	31.5	37.4	31.1	34.5	23.5	44.3	23.0	48.2	27.5	23.0	4
Falmouth	42.5	33.2	37.7	30.3	32.8	25.7	39.7	24.1	46.5	38.8	24.1	4
Channel Islands.												
Scilly	44	37	39	36	36	30	46	31	55	34	30	3
Guernsey	42.5	31.7	35.9	35.5	32.9	27.2	44.1	27.5	49.4	29.5	27.2	3
Jersey	41	30	40	35	33	26	44	21	49	23	21	4

SHEFFIELD.—Min. 28°·1. Temperature was slightly lower on March 4th, 1889; and on March 5th, 1886.

BUXTON.—Min. 10°·9. 10°·2 was recorded on March 3rd, 1887, and 9°·4 on March 4th, 1889.

SOUTHWELL.—Min. 17°·2. 15°·8 recorded on March 4th, 1889.

STRELEIGH.—Min. 18°·2. Twice lower in March since 1880; 18°·8 March 7th, 1886, 15°·2 March 10th, 1888. Also one other winter temperature lower in 10 years, 0°·8, January 15th, 1881.

BELPER.—Min. 19°·1. There have been three Marches with lower temperatures during the last 18 years, viz. 1889, 1886, and 1888.

UPPINGHAM.—Min. 19°·9. Lower temperatures were experienced in March 1888 and 1889, and often in recent winters: the absolutely lowest since 1876 is 9°·5 on January 16th, 1881.

RUGBY.—Min. 17°. The thermometer registered 16°·6 on January 6th. A lower reading was observed in March 1886, the thermometer registering 15°·6; and in several recent winters lower temperatures have been recorded.

ASPLEY GUISE.—Min. 16°·2. The lowest reading in March since observations were commenced in 1871, but lower in several recent winters. Lowest temperature recorded 6°·9 on January 22nd, 1881.

ROSS.—Min. 15°·8. The only instance of a lower temperature in March was 15°·0 March 1st, 1866. Lower in 11 winters during the last 25 years, lowest 1°·8 December 31st, 1870.

CHELTEMHAM.—Min. 15°·2. During the last 12 years lower temperatures have occurred twice in March, 12°·2 March 25th, 1878; 11°·2 March 16th, 1877. The temperature has fallen lower each winter except 1881-2, 1882-3, 1888-4, and 1884-5. The lowest temperature was —8°·8 January 20th, 1881.

BERKHAMSTED.—Min. 18°·8. No March with so low a temperature since observations were commenced in 1886, but each winter has had a lower reading with the exception of 1887-8.

ENGLAND, E.

SOMERLEYTON.—Min. 15°·1. No instance of so low a temperature in March since 1870, but a lower reading observed in 10 winters out of the 20.

ROYSTON.—Min. 15°·8. No reading so low in March during the last 39 years, but lower winter temperatures were observed in 18 years, the lowest was 1°·1 December 25th, 1860.

ENGLAND, S.

LONDON.—St. Luke's, Old Street.—Min. 20°·9. No record so low since observations commenced in 1888.

LONDON.—Holland House, Kensington.—Min. 16°. The shade temperature fell to 15° on December 31st, 1886.

LONDON.—Lansdowne Crescent, Notting Hill.—Min. 18°·8. Observations date from January 12th, 1879. No previous record so low in March. Lower readings in past winters, 11°·2 January 15th, 1881, 15°·2 January 2nd, 1887, 15°·4 December 7th, 1879, 17°·8 February 18th, 1889, 18°·2 January 7th, 1886. The range of temperature during March was 48°·7, which is the greatest range in any month during the last 12 years, excepting 50° in July 1881.

LONDON.—Camden Square.—Min. 15°·6. Observations commenced in 1859. No other record so low in March. Lower readings in past winters, 6°·7 December 1860 and January 1867, 11°·8 January 1881, 14°·0 December 1870, 14°·8 January 1861, 14°·4 December 1859, 14°·5 January 1887, 15°·1 January 1864, 15°·4 February 1865.

LONDON.—Royal Botanic Society's Gardens.—Min. 16°·5. Observations commenced in 1870. No previous record so low in March. Lower readings in past winters, 9°·8 in 1880-1, 12°·5 in 1879-80, 14° in 1878-4 and 1878-9, 15°·5 in 1875-6.

CROYDON.—Whitgift Grammar School.—Min. 10°. No record so low during the last six years.

ADDISCOMBE.—Min. 8°·5. No record so low since observations were commenced in 1878, 17 years. The young foliage on the roses was entirely destroyed.

WADDON.—Min. 17°. Once lower in March since 1882, reading 11°·6 March 7th, 1886. Lower readings in previous winters 8° January 8th, 1886, 10° January 2nd, 1887, 11° December 22nd, 1886, 11°·6 January 7th, 1887, 12°·4 January 7th, 1886.

BEDDINGTON.—Min. 5°·4. No record so low during the last 10 years.

KENLEY.—Min. 6°. No record so low, but observations for two years only.

WALLINGTON.—Min. 9°·8. No record so low since observations were commenced in 1884.

EGHAM.—Cooper's Hill.—Min. 19°·1. The thermometer fell to 19° on December 29th, 1889, and lower readings have been recorded in eight previous winters since 1874; the minimum during the period was 8°·5 on January 15th, 1881.

CANTERBURY.—Miss Metcalfe, referring to the early morning of 4th, writes

TABLE II.

HOURLY RECORDS OF TEMPERATURE AT GREENWICH, KEW AND FALMOUTH.

Hour.	March 3rd.						March 4th.					
	Greenwich.		Kew.		Falmouth.		Greenwich.		Kew.		Falmouth.	
	Air.	Wet Bulb, Difference below.	Air.	Wet Bulb, Difference below.	Air.	Wet Bulb, Difference below.	Air.	Wet Bulb, Difference below.	Air.	Wet Bulb, Difference below.	Air.	Wet Bulb, Difference below.
1 a.m.	22.1	0	23.2	0	27.7	3.7	22.8	0	24.5	2.2	26.9	3.9
2 "	22.4	0	22.4	0	27.2	3.2	22.0	0	23.1	1.6	27.2	3.2
3 "	22.8	0	22.9	0	26.9	2.8	19.8	0	22.2	1.5	26.6	2.7
4 "	23.1	0	23.4	0	26.8	2.6	18.9	0	20.3	0.9	25.5	2.2
5 "	22.7	0	23.7	0	26.8	2.4	18.4	0	19.8	0.9	25.1	1.9
6 "	22.4	0	23.6	0	26.0	2.0	15.2	0	19.1	0.4	24.0	1.8
7 "	21.6	0	23.2	0	25.3	2.1	14.1	0	18.4	0.4	24.1	2.0
8 "	22.9	0	23.5	0	25.9	2.3	15.3	0	20.0	1.0	24.6	1.8
9 "	25.0	2.2	24.2	0	27.6	2.6	19.2	0.9	24.2	1.4	27.0	2.0
10 "	27.6	0	26.5	0	29.6	2.6	24.0	0	27.0	2.4	30.1	0
11 "	30.4	0	28.9	0	30.7	2.9	27.8	0	29.4	3.8	32.9	3.7
Noon	31.9	3.9	30.2	0	31.0	4.0	31.8	3.8	31.0	4.3	33.9	4.0
1 p.m.	31.8	0	30.7	4.8	31.4	4.6	32.7	0	33.2	5.1	35.1	4.2
2 "	31.5	0	31.0	4.8	31.8	4.5	32.6	0	33.7	5.0	36.3	4.7
3 "	31.3	4.5	31.0	5.0	31.8	4.8	32.5	4.0	34.3	5.3	36.2	4.3
4 "	30.3	0	30.7	5.0	31.6	4.5	32.9	0	33.2	5.1	36.8	4.8
5 "	29.0	0	29.9	4.4	31.7	4.7	31.5	0	32.9	4.6	35.3	3.1
6 "	28.1	0	29.2	3.1	30.8	4.2	30.1	0	32.0	4.0	34.7	3.0
7 "	26.8	0	28.0	2.6	29.7	0	29.2	0	31.0	3.2	35.0	3.0
8 "	26.5	0	26.3	1.7	29.2	4.3	29.2	0	31.0	3.2	36.5	2.6
9 "	25.4	1.3	25.7	1.8	27.3	3.1	30.4	2.9	31.7	3.6	38.1	2.5
10 "	25.1	0	25.0	2.0	26.0	2.6	31.4	0	31.9	3.1	39.1	2.1
11 "	25.2	0	25.0	2.2	26.1	3.3	31.4	0	32.7	1.7	40.0	1.5
Midnt.	24.7	0	25.3	2.2	25.1	2.9	32.6	0	34.0	2.1	40.1	0.5

that a large rose grower in Canterbury had by this severe night lost nearly £800 worth of roses.

BROCKHAM.—Min. 9°. All unprotected tea roses killed to the ground; also many hybrid perpetual roses.

DORKING.—Min. 14°. Temperature has fallen lower only in four winters since observations were commenced in 1870, these were 11° December 28rd, 1870, 18° January 8th, 1876, 12° January 15th, 1881, 12° January 17th, 1887.

BECKENHAM.—Min. 7°-8. Mr. Bicknell notes there has been skating in March in four consecutive years, a very rare, probably unprecedented, occurrence.

1887. March 21st. Skating in St. James's Park.

1888. Several days up to and including March 5th.

1889. March 6th.

1890. March 4th and 5th.

} At the Skating Club,
Regent's Park.

ELTHAM.—Min. 10°. The lowest reading during eight years that observations have been made; the next lowest was 13° on January 17th, 1887.

MARLBOROUGH.—Min. 12°-9. In March 1887 the shade thermometer fell to 4°-5, and lower readings than in March this year were recorded in eight winters since 1865.

HARESTOCK.—Min. 16°-6. No March reading so low since observations were commenced in 1860, but lower readings in two winters, viz. 10°-1 on January 17th, 1881, and 14°-5 on January 1st, 1887.

CRANBROOK.—Min. 10°. With the exception of 4° on January 22nd and 8° on

TABLE III.

HOURLY RECORDS OF BAROMETER AT GREENWICH, KEW AND FALMOUTH.

Hours.	March 3rd.						March 4th.					
	Greenwich.		Kew.		Falmouth.		Greenwich.		Kew.		Falmouth.	
	Barometer.	Hourly Change.	Barometer.	Hourly Change.	Barometer.	Hourly Change.	Barometer.	Hourly Change.	Barometer.	Hourly Change.	Barometer.	Hourly Change.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
1 a.m.	30'175	..	30'343	..	30'177	..	30'296	—'004	30'457	'000	30'306	—'013
2 "	'184	+ '009	'355	+ '012	'175	—'002	'283	—'013	'440	—'017	'300	—'006
3 "	'175	—'009	'349	—'006	'176	+ '001	'274	—'009	'437	—'003	'281	—'019
4 "	'180	+ '005	'346	—'003	'181	+ '025	'255	—'019	'424	—'013	'263	—'018
5 "	'180	'000	'353	+ '007	'185	—'004	'257	+ '002	'423	—'001	'252	—'011
6 "	'196	+ '016	'366	+ '013	'201	+ '016	'250	—'007	'416	—'007	'254	+ '002
7 "	'232	+ '036	'397	+ '031	'225	+ '024	'253	+ '003	'416	'000	'257	+ '003
8 "	'267	+ '035	'431	+ '034	'247	+ '022	'264	+ '011	'424	+ '008	'256	—'001
9 "	'294	+ '027	'460	+ '029	'257	+ '010	'254	—'010	'419	—'005	'253	—'003
10 "	'305	+ '011	'469	—'009	'259	+ '002	'236	—'018	'403	—'016	'247	—'006
11 "	'310	+ '005	'473	+ '004	'259	'000	'215	—'021	'380	—'023	'238	—'009
Noon	'315	+ '005	'471	—'002	'267	+ '008	'203	—'012	'361	—'019	'230	—'008
1 p.m.	'310	—'005	'467	—'004	'271	+ '004	'155	—'048	'311	—'050	'204	—'026
2 "	'305	—'005	'460	—'007	'263	—'008	'117	—'038	'267	—'044	'173	—'031
3 "	'294	—'011	'455	—'005	'261	—'002	'082	—'035	'235	—'032	'143	—'030
4 "	'284	—'010	'441	—'014	'261	'000	'052	—'030	'212	—'023	'131	—'012
5 "	'292	+ '008	'447	+ '006	'265	+ '004	30'030	—'022	'182	—'030	'101	—'030
6 "	'295	+ '003	'452	+ '005	'281	+ '016	29'996	—'034	'149	—'033	'091	—'010
7 "	'300	+ '005	'459	+ '007	'301	+ '020	'965	—'031	'125	—'024	'063	—'062
8 "	'302	+ '002	'460	+ '001	'319	+ '018	'926	—'039	'079	—'046	'040	—'039
9 "	'298	—'004	'456	—'004	'323	+ '004	'870	—'056	30'031	—'048	30'017	—'014
10 "	'305	+ '007	'464	+ '008	'325	+ '002	'823	—'047	29'979	—'052	29'973	—'006
11 "	'310	+ '005	'471	+ '007	'321	—'004	'785	—'038	'941	—'038	'937	—'004
Midnt.	30'300	—'010	30'457	—'014	30'319	—'002	29'744	—'041	29'897	—'044	29'881	—'016

January 23rd in 1881, no lower reading has been observed during the last 25 years. The next lowest reading in March was 19° on the 11th, in 1874.

TENTERDEN.—Min. 14°. Nothing lower since January 1881, when 10° was registered on the 22nd. Mr. Mace remarks: "Shrubs are not much out up here, but on low ground at Pluckley, Bethersdon, Headcorn, and Romney Marsh, they are badly damaged, evidencing much lower temperatures." He has also heard of a Six's thermometer falling to 6° at Tenterden, but it was not properly screened. The time of greatest cold is thought by men who were out early to have been about 6 a.m., and as not having been nearly so keen at an earlier hour.

PARKSTONE.—Min. 18°. This is the lowest temperature registered since observations were commenced in April 1882, the next lowest was 18°·2 December 11th, 1882.

EASTBOURNE.—Min. 19°·5. Lower in three winters since records commenced in 1880. 14° in January 1880, 12°·8 in January 1881, 17°·9 in February 1888.

BRIGHTON.—Min. 20°. No record of such cold in March, at any rate not for the last 45 years.

WORTHING.—Min. 19°·4. Observations recorded since 1855. One instance of a lower March temperature, 18° in 1867. During the 85 years a lower winter temperature has occurred in 6 years.

TOTLAND BAY, I. W.—Min. 28°. The lowest reading during the last four years.

SOUTHBORNE-ON-SEA.—Min. 18°·4. The lowest record in March during the

TABLE IV.

HOURLY RECORDS OF WIND AT GREENWICH, KEW AND FALMOUTH.

Hour.	March 3rd.						March 4th.					
	Greenwich.		Kew.		Falmouth.		Greenwich.		Kew.		Falmouth.	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
		Miles.		Miles.		Miles.		Miles.		Miles.		Miles.
1 a.m.	NE	16	NNE	13	NE	23	NE	6	N	8.5	NEbN	9.5
2 "	NE	15	NbE	15	NE	23	NE	6	N	6.5	NEbN	7.5
3 "	NNE	18	NbE	15	NE	20	N	1	N	5.5	NEbN	5.5
4 "	NNE	13	NbE	16	NEbN	19	E	1	N	3	NEbN	6.5
5 "	NNE	17	NbE	14	NEbN	18	NNE	1	N	2	NE	4.5
6 "	NE	13	NNE	16	NE	22	W	1	N	2	NE	4.5
7 "	NE	9	NEbN	15	NE	21	W	4	N	3	NE	4.5
8 "	NE	8	NEbN	8.5	NE	21	SW	3	N	2	NE	4.5
9 "	NE	6	NEbN	7.5	NE	23	SW	6	N	4	NE	6.5
10 "	NE	10	NEbN	7.5	NE	26	SW	3	N	5.5	NEbN	4
11 "	NNE	10	NE	17	NE	25	WSW	9	NWbW	5.5	ENE	7.5
Noon	NNE	19	NEbN	16	NE	24	WSW	10	WSW	8.5	EbN	6.5
1 p.m.	NNE	18	NEbN	15	NE	24	SW	11	SW	10.5	E	4.5
2 "	NNE	18	NNE	17	NEbE	22	SW	12	SSW	14	SSE	5.5
3 "	NNE	15	NbE	18	ENE	18	SW	13	SW	14	SbE	6.5
4 "	NNE	16	NbE	16	NEbE	18	SW	16	SWbW	14	S	5.5
5 "	NNE	15	NbE	11	NEbE	15	SW	14	SW	13	SSW	8.5
6 "	NNE	11	NbE	14	NE	16	SW	14	SW	13	WSW	12
7 "	N	13	NbE	10.5	NE	13	SW	19	SWbS	15	WSW	12
8 "	N	14	NbE	9.5	NE	13	SW	19	SWbS	18	WbS	17
9 "	N	10	N	10.5	NEbN	7.5	SW	22	SW	17	WSW	19
10 "	N	11	N	10.5	NEbN	7.5	SW	23	SW	16	WbS	24
11 "	N	10	N	9.5	NEbN	6.5	SW	26	SW	16	WbS	25
Midnt.	NNE	9	N	9.5	NEbN	5.5	SW	25	SWbW	16	WbS	27

last 24 years. Only five winters with so low a temperature—the lowest $10^{\circ}5$ on January 14th, 1867.

ROUSDON.—Min. $18^{\circ}2$. The lowest reading since observations were commenced in 1888.

ENGLAND, S.W.

ST. DAVID'S.—Min. $24^{\circ}2$. No record of so low a reading in any winter since observations were commenced in 1878, the next lowest was $24^{\circ}4$ March 2nd, 1888.

WESTON-SUPER-MARE.—Min. $21^{\circ}2$. Lower than in any March since observations were commenced in 1888, but lower readings occurred in January 1887 and 1889.

ILFRACOMBE.—Min. $28^{\circ}6$. The temperature fell to 28° March 11th, 1886.

ASHBURTON.—Min. $22^{\circ}6$. No March reading so low since observations were commenced in 1881, but lower in two winters, $15^{\circ}3$ January 22nd, 1881, and $20^{\circ}7$ February 25th, 1888.

BABBAcombe.—Min. $24^{\circ}5$. Lower in March in five years since 1876, and lower in nearly every winter; lowest $15^{\circ}3$ January 20th, 1881. Vegetation very much burnt up. The dryness throughout the frost was very remarkable.

GUERNSEY.—Min. $27^{\circ}8$. Observations from 1881 do not show so low a record in March.

TABLE V.—GREENWICH TEMPERATURES, 1841-90.

Year.	March.										Winter.									
	Shade Temp.					Shade Temp.					Shade Temperature.									
	Range.			Min.		Max.			Monthly Mean.			Year.		Date.						
	Day.	Min.	Max.	Day.	Min.	Max.	Max.	Min.	Max.	Year.	Date.	Lowest Temp.								
1841	26	66°	2	29°	37°	26°	56°	38°	47°	1840-1	Jan. 9, '41	4°	1866	Mar. 1, '66	22°					
1842	28	60°	5	26°	35°	21°	50°	37°	43°	1841-2	Nov. 17, '41	22°	1867	Jan. 5, '67	6°					
1843	18	63°	7	31°	40°	28°	54°	40°	48°	1842-3	Feb. 15, '43	20°	1868	Dec. 9, '67	21°					
1844	29	60°	6	24°	36°	12°	48°	35°	42°	1843-4	Jan. 3, '44	18°	1869	Nov. 6, '68	26°					
1845	27	59°	14	23°	31°	15°	47°	30°	36°	1844-5	Feb. 12, '45	7°	1870	Feb. 11, '70	19°					
1846	31	58°	21	26°	31°	7°	42°	38°	44°	1845-6	Mar. 21, '46	26°	1871	Dec. 25, '70	9°					
1847	17	64°	11	16°	47°	3°	50°	34°	42°	1846-7	Feb. 12, '47	11°	1872	Dec. 8, '71	18°					
1848	31	71°	4	28°	43°	18°	51°	37°	44°	1847-8	Jan. 28, '48	16°	1873	Feb. 24, '72	25°					
1849	17	60°	25	27°	33°	21°	50°	36°	43°	1848-9	Jan. 3, '49	19°	1874	Feb. 11, '74	21°					
1850	31	58°	26	20°	38°	12°	48°	32°	40°	1849-50	Dec. 29, '49	18°	1875	Jan. 1, '75	18°					
1851	20	58°	9	29°	38°	23°	49°	37°	43°	1850-1	Feb. 17, '51	23°	1876	Jan. 8, '76	17°					
1852	23	68°	5	21°	37°	11°	50°	32°	41°	1851-2	Mar. 5, '52	21°	1877	Mar. 1, '77	23°					
1853	13	60°	5	20°	39°	12°	47°	31°	39°	1852-3	Feb. 19, '53	20°	1878	Mar. 25, '78	24°					
1854	13	64°	3	24°	39°	14°	55°	35°	45°	1853-4	Jan. 3, '54	13°	1879	Dec. 25, '78	12°					
1855	20	57°	10	24°	33°	15°	46°	31°	39°	1854-5	Feb. 19, '55	11°	1880	Dec. 7, '79	13°					
1856	31	58°	30	24°	33°	8°	45°	33°	39°	1855-6	Dec. 22, '55	16°	1881	Jan. 17, '81	12°					
1857	18	66°	22	27°	38°	15°	50°	35°	43°	1856-7	Dec. 28, '56	18°	1882	Dec. 24, '81	21°					
1858	24	68°	11	23°	45°	15°	50°	33°	42°	1857-8	Jan. 6, '58	20°	1883	Mar. 24, '83	20°					
1859	5	63°	51	28°	34°	19°	54°	40°	47°	1858-9	Nov. 24, '58	20°	1884	April 23, '84	27°					
1860	28	59°	50	23°	36°	21°	49°	35°	42°	1859-60	Dec. 19, '59	14°	1885	Jan. 22, '85	22°					
1861	24	61°	14	20°	32°	16°	52°	37°	44°	1860-1	Dec. 25, '60	8°	1886	Jan. 7, '86	16°					
1862	24	63°	6	22°	41°	14°	50°	38°	44°	1861-2	Jan. 19, '62	20°	1887	Jan. 2, '87	15°					
1863	3	64°	18	28°	35°	22°	53°	37°	44°	1862-3	Nov. 23, '62	24°	1888	Feb. 2, '88	18°					
1864	4	58°	24	26°	31°	19°	49°	34°	42°	1863-4	Jan. 7, '64	14°	1889	Mar. 4, '89	18°					
1865	31	58°	21	23°	35°	20°	44°	31°	37°	1864-5	Feb. 15, '65	15°	1890	Mar. 4, '90	13°					
Mean	...	62.2...	24.9	37.3	16.1	50.0	35.3	42.7	...	Mean	...	...	...	...	186	
25 years, 1841-65	...	62.2...	24.9	37.3	16.1	50.0	35.3	42.7	...	25 years, 1866-90	...	61.6...	24.4	37.2	18.5	49.4	34.7	42.1
Mean	...	61.9...	24.7	37.2	17.3	49.7	35.0	42.4	...	Mean	...	61.9...	24.7	37.2	17.3	49.7	35.0	42.4
50 years, 1841-90	...	61.9...	24.7	37.2	17.3	49.7	35.0	42.4	...	50 years, 1841-90	...	61.9...	24.7	37.2	17.3	49.7	35.0	42.4

Tables II. III. and IV. give the hourly values of temperature, pressure, and wind obtained from the continuous records. The absolutely lowest temperature occurred at 6.50 a.m. on the 4th, both at Kew and Falmouth, and was said to be shortly before 7 a.m. at Greenwich. It will be seen that the air was very dry at all three observatories for some hours before and after the period of greatest cold, also that the fall of barometer which was in full progress at the commencement of the 4th, due to the southerly movement of the high pressure system and the incoming influence of the approaching cyclonic disturbance, was checked about the time of maximum cold, and a slight temporary rise is shown at each observatory; this movement is equally well marked after applying the diurnal range correction. The wind observations show a calming down of the atmosphere, the movement of the air being almost imperceptible for a few hours when the temperature was at its lowest. The latter feature is by no means uncommon during periods of very low temperature, and is doubtless intimately associated with intense radiation. In the present case, however, the terrestrial radiation was exceptionally small, a fact which was very prominently noticed by several observers. The hourly values certainly seem to point to a descending current of air, but proof of this is by no means easily secured.

At Greenwich the thermometer in the shade registered $18^{\circ}\cdot 1$ on the 4th, which has only once been equalled in March during the last 100 years, a precisely similar reading having occurred on March 14th, 1845. During the last half century the temperature in March has previously fallen below 20° in three years only, whilst, during the whole winter, so low a temperature as $18^{\circ}\cdot 1$ has only occurred in eight years.

On the grass, exposed to the sky, the thermometer at Greenwich fell to $8^{\circ}\cdot 6$, which is lower than in any March since 1856.

An unusually high temperature also occurred at Greenwich during March, the shade thermometer registering $68^{\circ}\cdot 8$ on the 28th, a reading which has only been exceeded in March on two days during the last 50 years. The range of temperature at Greenwich, which amounted to $55^{\circ}\cdot 7$, was larger than in any March during the last half century.

Table V. gives the Greenwich temperatures during the last half century for March, as well as the lowest shade temperatures for each winter.

I would, before closing this paper, thank Mr. Scott and the Meteorological Council for allowing me free use of the information in the Meteorological Office, also Mr. Marriott and the Royal Meteorological Society for the use of its valuable returns. I would also acknowledge the ready assistance given by Mr. Symons, and by all who have so cordially assisted by the prompt supply of their observations.

DISCUSSION.

Surgeon-Major HALE inquired whether Mr. Harding could mention a possible or probable cause of the very low temperatures recorded in Surrey, as from its southerly position the cold might reasonably be expected to be less severe there than in more northern localities.

Mr. ROSTRON remarked concerning Dr. Hale's inquiry, that possibly the low temperatures experienced in Surrey were due to the natural configuration of the district. His house at Beddington, where a minimum temperature of 5° was registered, was situated close to the river Wandle, running East and West, and laid low. The soil was chalk. One feature in connection with the weather experienced during the month was the extraordinary range of temperature, the difference between the extreme temperatures recorded being 62°. He should like to know whether so large a range had ever been observed in any other month.

Mr. GASTER said it was a comparatively easy matter to explain the meteorological conditions over the British Isles which caused the spell of cold weather as felt over the kingdom generally at the commencement of March: but the extreme cold experienced in certain parts of Surrey and Norfolk did not admit of easy explanation, and in fact he could not at present pretend to account for the severity of the frost in those districts at all. He proceeded to illustrate on the blackboard the distribution of pressure over Scotland and England during the first four days of March, and described in detail the progress Southwards of the anticyclone from day to day, showing how these changes had produced the frost experienced over the country at large on the 3rd and 4th. An examination of the thermograms from the Glasgow Observatory during this period proved that on the 3rd, under the influence of an incoming Westerly breeze, the temperature rose from about 25° at 6 a.m. to 39° by about 1 p.m.: during the following night the air maintained this temperature, there being hardly a degree of variation throughout the night, while over England, where Easterly breezes or anticyclonic air still held, the thermometer fell fast. But the difficulty was to explain why, just in certain limited portions of the South-east of England, such exceptionally low readings should have been recorded. Terrestrial radiation was slight, so the extreme cold could not have been due to that cause. He could only surmise that some down-draught of air might have occurred locally and produced the intense cold, but of this there was at present no evidence before the Society.

Dr. MARCET said that on reaching his house in Wimbledon Park on Tuesday, March 4th, about 11.30 p.m., he went to his thermometer screen and found the temperature was, as far as he recollected, 28°. The next morning the minimum thermometer indicated 18°·8, showing that the minimum must have occurred sometime between midnight and sunrise. He had frequently observed the temperature to be lower about 8 or 9 p.m. than at 11 or 12 p.m. the same night. The maps illustrating Mr. Harding's paper showed that the sea-side stations were much warmer than those inland. He should like to know whether Mr. Harding had any records of the temperature of the sea on the South and East coasts, and also whether sea-fog was prevalent on the morning of the 4th, as there must have been considerable difference between the temperature of the sea and the temperature of the air.

Mr. SYMONS said that respecting the area of greatest cold, he had been very much surprised, when investigating the frost of 1867, to find how severe that frost was in the Thames Valley. The frosts of 1838, 1860, and 1867 were all very severe in the same district. It would be interesting if observations concerning the changes of wind at Greenwich Observatory or elsewhere in March 1890 could be given, as evidence might thus be obtained of any down-draught of air, such as mentioned by Mr. Gaster.

Mr. SOUTHALL remarked that Mr. Symons appeared to class the frosts of 1860 and 1867 together. Possibly in the Thames Valley these frosts may have been similar, but the frost of 1860 was the much more severe of the two in the Wye valley. On March 18th, 1845, the Wye was frozen over at Ross; a phenomenon which does not occur once in a space of 50 years. A fair was held at the time, and it was stated that icicles a foot long hung from the animals' mouths.

Mr. BAYARD said that on January 7th and 8th, 1886, during a similarly cold period in this same district in Surrey, some very low temperatures were registered. The figures were printed in *Symons's Monthly Meteorological Magazine* for 1886, p. 11.

Mr. TRIPP remarked that some years ago, when in South Africa, he had made observations of air temperatures at two adjacent stations, one situated on a hill, and the other in a valley; and had found that the extremes recorded were much

greater in the valley than they were on the hill, while the means were much the same.

Mr. DINES inquired if there was any record of the depth of snow on the ground, as he thought these low temperatures generally occurred in the deep snow. At Hersham the temperature fell to $18^{\circ}8$, but there was no snow, and this low temperature struck him as being very remarkable.

Mr. ROSTRON said that at Beddington there were two inches of snow on the ground.

Mr. MARRIOTT said he was much struck, when reading his instruments on the mornings of the 8rd and 4th, with the very little difference between the temperature of the air and that on the grass; and he did not think that the low temperatures recorded were due to radiation. There was no wind in the neighbourhood of London, but in the north a strong wind was blowing. Regarding Mr. Southall's remarks concerning icicles hanging from a horse's mouth, Mr. E. J. Lowe told him that during the winter of 1860 he had seen icicles of considerable length suspended from a horse's mouth.

Rev. G. T. RYVES gave particulars of the temperatures recorded at Tean, Staffordshire, during this cold period, and remarked that the most interesting point in connection with this frost was to explain why the extreme cold occurred where it did.

Mr. SOUTHALL inquired whether the effect of the low temperatures on vegetation was very marked.

Mr. ROSTRON said that he had noticed that Evergreens in the neighbourhood of Beddington were much shrivelled: Euonymas severely; Roses, Evergreen Oaks, Portugal Laurels badly, and even Yews were touched.

Mr. C. HARDING in reply said that respecting the cause of the extreme cold over parts of Surrey and Kent, he was inclined to the opinion that it was due to a down-draught of air. The whole district affected lay between the Easterly current of the anticyclone and the Westerly current of the cyclonic system to the North and West; the air being comparatively calm in the locality of the severe temperature. He hoped that the hourly readings from Greenwich, Kew, and Falmouth, which are given in the Paper, might help forward some explanation of the cause of the intense cold. Regarding the time at which the extreme temperature took place, Mr. Mace, at Tenterden, remarked that the greatest cold occurred at about 6 a.m., men who were out of doors stating that before that hour the air was not nearly so keen. He had hoped to make a comparison between the frost in March 1845 and that recently experienced. Mr. Glaisher had stated that the temperature experienced in 1845 was unprecedented. He had not been able to look into the question of sea temperature, but with regard to the condition of the sky during the period, the 8rd was clear, while the 4th was cloudy. He was surprised to hear that no snow remained on the ground in the neighbourhood of Esher, as in the suburbs of London the snow remained until well after the frost.

THUNDERSTORM & WHIRLWIND AT YORK,

SATURDAY, MARCH 8th, 1890.

By J. E. CLARK, B.A., B.Sc.

(Communicated by R. H. SCOTT, F.R.S.)

(Plate V.)

[Read April 16th, 1890.]

THE weather during the morning of March 8th had been rather unsettled, but without rain, and at noon showed sufficient signs of improvement for us to plan an afternoon expedition. Towards two o'clock, however, a heavy cloud began to gather in the North-west, and, soon after, thunder was heard. Approaching rather rapidly, rain began between 2.15 and 2.30, in the locality where I reside (I.).¹ This is on the outskirts of York, 600 yards due north of the Minster Chapter House (VIII.).¹ Soon hail began to fall, as the flashes became frequent and near; although they were not very vivid nor was the thunder very loud.

The hailstones came very thickly for 5 or 10 minutes, in some cases being as large as hazel nuts. The wind, West-by-north, was only strong enough to blow them in about 2½ or 3 feet at a doorway 7½ feet high. The hail outside was quite soft, the hard core being surrounded with irregular, snow-like masses, in a state of semi-slush. Enough fell here just to whiten the ground. The fall is said to have been heavier and the stones larger in the central and southern parts of York, especially in Parliament Street. There, however, the weekly uncovered market made it so unwelcome as to produce exaggeration. The size was given "as big as one's thumb."

Although there is no rain-gauge in the central parts, the amount did not probably vary very much, as the following totals indicate. The order is from North to South :—

			From Minster Chapter House.	Rainfall. Ins.
II. Bootham School gauge	...	1,400 ft.	50° W of N	0·17
III. Museum gardens	..	1,800 ft.	110° W of N	0·15
IV. Cherry Hill	..	8,450 ft.	175° W of N	0·18
V. Mount School	..	5,150 ft.	150° W of N	0·17
VI. Mount Villas ²	..	8,800 ft.	155° W of N	0·17

¹ These numbers refer to references on the map (Plate V.). Roman numerals to points in the City. Plate V. is a reproduction of the Ordnance Survey Map on a reduced scale.

² These numbers also include slight falls later in the day.

During the storm it grew very dark, yet not so as to make lights necessary. The cloud passed over to the South-east, we being apparently on its North-eastern fringe. The lightning was nearer on the South of York. Two of our boys, from Bootham School, were returning up the steep bit of hill from the race-course to the Mount (VII.), when a vivid flash was accompanied by simultaneous thunder, "which quite made me," says the writer, "feel funny." It "struck a pool of water about 4 feet in front of us, and sent the water aside to right and left." I should judge that the main flash was more distant, the splash being due to one of its ramifications along the drenched highway.

The storm was equally violent in other parts of the East and West Ridings. I noticed limbs off two trees near the point where the North Eastern Railway crosses the Wharfe at Bolton Percy. At Dewsbury it attracted considerable attention, and it has been reported to me from Rawdon, near Leeds, and from Bradford, where it occurred at 2 p.m., or about half an hour sooner than at York. At Huddersfield, too, the record was "thunderstorm from 2 p.m." At Driffield, 28 miles East-by-north, occurred "Heavy thunder overhead at 8.25; squall of wind and rain from West-north-west at 4.15; force 5."

At my house all was practically over at 2.45, and there were at first signs of the afternoon clearing, although rather a strong South-westerly breeze was now blowing. The wind, however, came at times in very strong gusts, often accompanied with slight showers, from a little South of West.

Of the "whirlwind" I did not hear before Monday, and could not go to see any of its effects until three weeks later. Since then I have examined its course, except just at Water Fulford, and after it had crossed the long approach to Tilmire Common. Some of our boys¹ kindly investigated its track East of the Ouse on half-holiday afternoons, by aid of a tracing from the 6-inch Ordnance map.

A fairly correct account is given in the *Yorkshire Herald*, March 10th. The *Yorkshire Chronicle* mentions that, at Heslington, a woodshed belonging to Mr. Hills was blown down.

Outside the narrow track no damage whatever appears to have been done near York. The time was given me by the Head Gardener at Bishopthorpe as 2.40 or 2.45 p.m. Both he and Captain Key, at Rose Hall, Water Fulford (*vide infra*), noted that it was during the thunder and lightning. As Bishopthorpe is $8\frac{1}{4}$ miles South-by-west from my house, the course of the thunderstorm makes this agree with the time when it would be drawing to a close.

The gardener informed me that the wind had begun to rise some five

¹ Egbert C. Morland, after preliminary surveys on the 10th, went over the ground from "38" to "75" on the 12th, with C. H. Merz. On the 15th F. G. Fryer and A. Beale worked backwards from Heslington ("110" to "79"). W. Stephens noticed "37" on the 8th, an hour after the storm, but did not see the havoc across the river! J. H. Fryer and E. C. M. noted "111" and "112" on the 19th; on the 26th J. P. J. Malcomson and L. Baker took a few photographs. I have examined Nos. "1" to "37" and "55" to "98"; also "38" to "64" from across the river, except "48" to "51."

minutes before, and that there had already been some strong gusts. He was just outside his back-door, looking North over the Archbishop's kitchen gardens. So deafening was the rush of wind that he was not aware until after, of the destruction of two magnificent elms, not 80 yards away, nor of the branches torn from other trees along the road-side on his right, and in sight of him.

On April 2nd, Mr. Richard Thompson called upon Capt. W. H. Key, of Rose Hall,¹ 4,800 ft. East-north-east from this cottage. He was with his foreman in the fields near by. They had taken shelter in a strongly-built hut, within 100 yards of four of the shattered trees, yet nothing was heard except the wind.

According to the gardener the gust lasted about half a minute. "It was over before we had time to be frightened, or run out to see what it was," said the good woman of a cottage near Rose Hall.

The first undoubted signs of damage are at a point nearly South-south-west (155° W of N) from the Minster Chapter House, and exactly 8 miles away. The cyclone ended $2\frac{1}{2}$ miles to the South-east-by-east (120° E of N), having travelled $8\frac{1}{2}$ miles, measured in a straight line, from West-south-west to East-north-east (69° E of N). Slight detours make its whole track about $4\frac{1}{2}$ miles in length.

Two hundred yards West-south-west of the first barn is a small plantation. From this, possibly, a few small larch branches were torn off; but, as woodmen had been at work, it was difficult to be certain. Copmanthorpe lies just a mile further westward. Here there are no signs of any damage.

The course of the storm to the Archbishop's grounds, $\frac{1}{2}$ of a mile, is a straight line. Thence it swerved slightly northwards along the Ouse, affecting at first only the North bank of this North-east-by-east reach. Then, suddenly, two fields before Rose Hall, much damage began on the south bank. Its direction continued unchanged over Water Fulford.

Here the Ouse comes down from the North-west-by-north, making a bend of more than a right angle. The North-east-by-East line, however, is continued by a small stream or drain, 4 to 5 ft. wide, running to Heslington.

The storm continued up this to a point $1\frac{1}{2}$ miles from the gardener's cottage, and two fields short of the Tilmire approach. Here it seems to have been deflected, springing up again to the South-east; for only a few twigs are touched on a single tree in the next 800 yards, whilst two trees 400 yards to the South-east are much damaged. Tilmire appears to have been reached along this same line, 500 yards from the original direction. Towards this it now turned, or rather, perhaps, the storm was resumed over the whole of this width. It narrowed down again, however, while approaching Heslington, but here an apple-tree was damaged 400 yards North of the main line. Reaching the road to Langwith it ended its serious damage by untilling another barn (and seems to have turned South-east, following the

¹ I have also had some correspondence with and verbal information from him.—J. E. Clark.

road to the corner of "Langwith Long Lane," where a small bough was taken off a corner tree).

We come next to the more serious damage done by the storm, and the evidences of its strength and extent.¹

The "barn" (1) (Plate V.) at which it began is now dismantled and roofless, its gables facing square to the storm. That at the South-west is under a well-grown oak. This tree was untouched, except in one or two small twigs, yet the gable-end of the barn was blown over. It formed a triangle of well-built brickwork, 18 ft. long, 7 ft. high, and 10 ins. thick. Nine hundred feet, almost due East of the barn, a few twigs were gone from an elm (9) between an untouched oak and ash, 85 yards apart. Nothing but small branches were touched on intermediate trees. The hedges, it may be noted, along the whole track are nearly all either parallel to or at right angles with the East-north-east storm-track.

In the next hedge, however, and nearly 100 yards East-north-east of (9), a large ash (10) was much wrecked. Four branches were off, one 89 ft. long and 1½ ft. in diameter. Another, 16 yards North of it (11), was untouched, and so was a thorn 60 yards to the South. Here, then, the track must have been very narrow. So it was 2,800 ft. from the barn, where an oak (15) on the far side of the road was injured, whilst ash trees (14) 20 yards North and South on the other side, were untouched.

Crossing the next field, it uprooted a fine ash (16), 2½ ft. in diameter, and at the next hedge three ashes (17, 18, 19), the outer ones 50 yards apart, were affected. In the next field a row of ashes were injured, and one (22), being unsound, was snapped off, although 8 ft. across. Then came the greenhouse and gardener's cottage (25). The former lost a chimney and the latter a few tiles. Across the road, in the Archbishop's grounds (26), two grand elms went down on the Southern edge of the track, a plane tree close to the more Southerly elm being untouched. The next three to the North along the roadside lost their tops, while hollies, &c., in between, suffered, the whole width being 60 yards. Slight damage was done over yet another 80 yards (28) and more among the trees within the grounds (29).

As it followed Wall Ridge Reach of the Ouse, the little damage done at first was to ashes in a hedge 20 or 25 yards back from the right bank (31, &c.). Two fields before Rose Hall, however, on the left bank, a row of fine elms, almost North and South (38, 39, 40) suffered severely. Three next the river were uprooted, one of 4 ft. diameter and 80 ft. high. The last affected, 180 yards South of this one, was snapped off at 20 ft., where it was 2½ ft. in diameter.

In this row was a rookery, and some rooks were actually killed by the falling branches, not being able to escape.

As the other bank of the Ouse was also affected the width of the storm track here must have been at least 250 yards, nor could it have been much less as it swept over the slight rise (of glacial clays and gravels) just at

¹ The positions of damaged objects are shown on the map, Plate V., by Nos. The positions of *undamaged* objects along the track of the storm are indicated by fainter Nos.

the river bend, on which Rose Hall is situate, with farm buildings and cottages. These, and the gardener's cottage above, are the only houses in the whole 4 miles, although the three villages of Bishopthorpe, Fulford and Heslington lay but 200 or 300 yards off the storm track.

Rose Hall (45) lost its South-east chimney and tiles. The inner North-east angle of the farm buildings beyond was untiled. Next, many stacks in the stack yard (49) were upset or scattered, the hay lodging in the trees to the East-south-east up to a height of 40 ft. Yet other stacks were most capriciously left untouched. A large and new Dutch barn (51) was turned over, landing the other side of the hedge. Just opposite here the barge of Mr. Palmer (47), under the North bank, broke from its stout moorings "as if they were cords," its little boat being swamped, whilst the barge itself rocked very much. Indeed the wind seems to have been as violent as anywhere in the half-mile between the above-mentioned elms and Dam Lands Lane. In the dip of the stream two ashes (58) and a splendid oak (55) were uprooted. The photographs exhibited to the meeting show this oak and an ash (57) near the other two, from which a bough 1 ft. in diameter was carried 50 ft. Others show a willow (41) near the great elms.

Many trees, especially willows, had the bark stripped off branches and twigs.

Crossing the field containing the great oak, we reach Dam Lands Lane, where were grouped (60) a barn, half untiled and blown askew, three shattered ashes and a demolished haystack, much hay from which was in the next two hedges, for a width of 50 yards. The storm seems to have contracted here to this width, and so to have remained until near the Tilmire Approach. Of over two dozen trees, injured in this $\frac{1}{4}$ mile section, none were snapped off or uprooted. Such began again upon its crossing the strip of common (89) and continued to Heslington (95, 100, 105, 110). One bough was blown right across the Common, 90 yards, into the opposite hedge.

Just before Tilmire Approach there was again a sudden development of activity to the South of the previous line of advance, so that the line of damage along its further hedge facing West-by-south is about 700 yards long. It again contracted towards the main line, but seems to have widened again at Heslington, spreading out to the North-east and South-east. After the barn (109) comes half a mile of treeless, newly-enclosed fields; beyond which fresh signs of damage have just been discovered.

Papers sent me by Mr. R. H. Scott show that the same, or simultaneous storms visited other counties on Saturday afternoon. Nottingham and Lincolnshire appear to have been affected about $1\frac{1}{4}$ hours later, and Leicestershire $2\frac{1}{4}$ hours later. Mr. C. J. Bromhead reports damage in Lincolnshire, especially the destruction of a windmill at Heckington. The wind velocity at Bidston, near Liverpool, at 2 p.m., was 34 miles per hour, West-south-west; "a high velocity for the station."

We come next to the barometric conditions. The 8 a.m. chart shows three depressions; 28.8 ins. North-west of Scandinavia, 28.8 ins. over Finland, and an approaching and increasing depression of 29.2 ins., or lower, North-west of Ireland. There were also two secondary depressions over the North Sea, and

apparently a third over, or South of, St. George's Channel. The high pressure area lay over the Pyrenees, 80.0 ins. Hence, naturally, the forecasts predicted "squalls, some rain."

At 2 p.m. (Fig. 1) pressure seems to have slightly increased over South-west France, and the three depressions had moved forward, that off Ireland giving 28.98 ins. as the reading at Malin Head. Pressures over England had decreased more than over the North Sea, where the isobars now bent northward. A well-marked secondary depression, of which the 8 a.m. chart gives no indication, lay North-west of York, the 29.2 ins. isobar curving sharply round on the South-south-east. A corresponding bend affects all the isobars from 29.1 ins. to 29.6 ins., their apices running in a curve from Dumfries, via York, Leicester, Oxford and Weymouth, to South of Land's End.

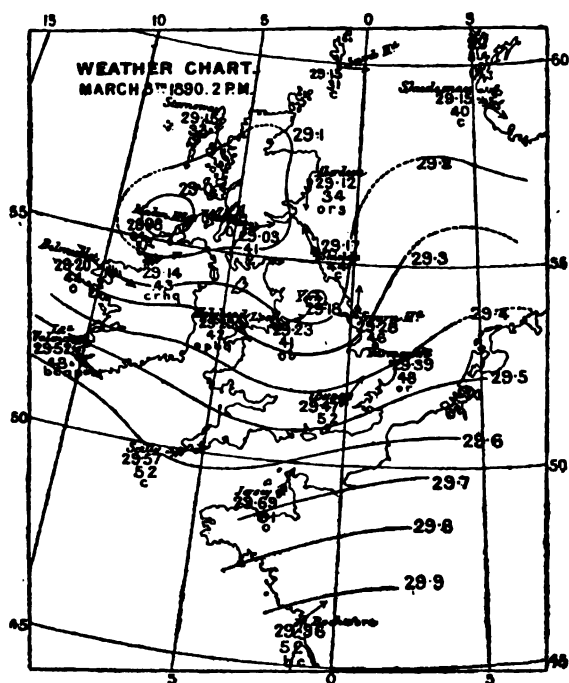


FIG. 1.

The secondary depression is well shown upon the accompanying 4 aneroidograms (Figs. 2-5). Taking that at York (which was about 10 minutes fast on the 8th), we see that a rapid fall during the morning was checked soon after 2 p.m., a slight rise occurring about 2.30. Then the fall continued until 3.30, when there was a yet more marked recovery, followed by a further slight fall until 10 p.m. At midnight there began a rapid and steady rise of over 0.9 ins. in 22 hours.

Three other barograms have been kindly supplied :—

(1.) Mr. C. L. Brook, of Meltham, near Huddersfield ; scale 5 inches to the barometric inch and $4\frac{1}{2}$ ins. to the day, clock right within 5 mins. ; this is 88 miles South-west from York.

(2.) Messrs. Reynolds and Branson, Leeds ; 28 miles South-west-by-west from York ; scale 2 ins. and $2\frac{1}{10}$; judged by York and Huddersfield, it would *seem* to be at least an hour fast.

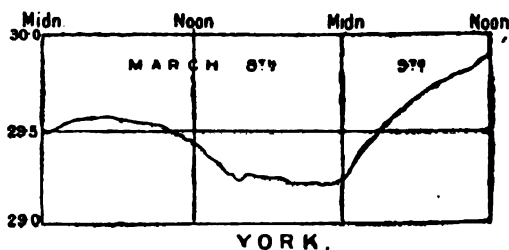


FIG. 2.

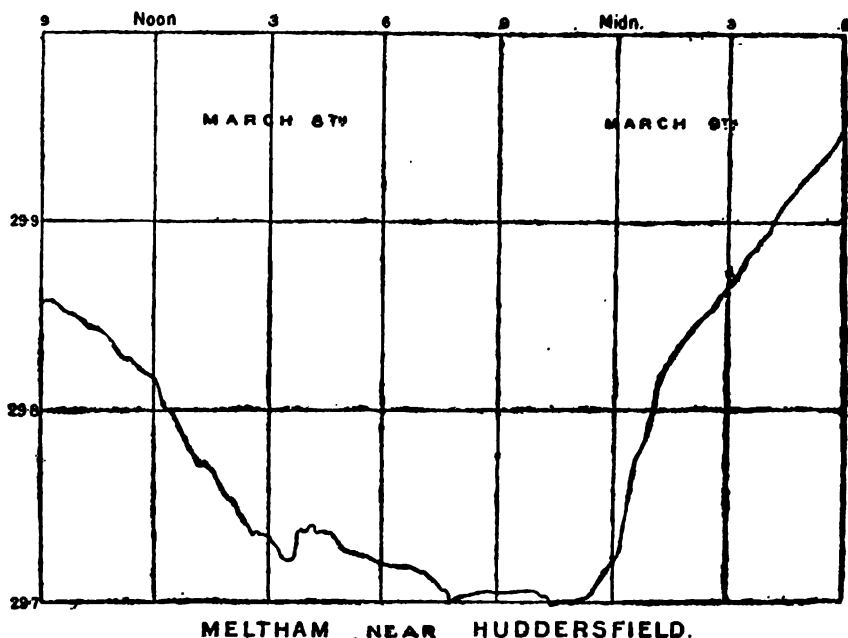


FIG. 3.

(8.) Mr. H. Mellish, Hodsock Priory, near Worksop ; 46 miles South from York. Scale same as York (Richard Frères of Paris), 1 in. by $1\frac{1}{2}$ in. ; corrections to mean sea level, -0.04 in. Clock a little fast.

They all bear a striking resemblance, showing the pause in the fall, the further fall, and sudden, almost perpendicular rise of 0.03 to 0.04 in.; a further gradual fall, soon after the cessation of which comes a very rapid, prolonged, steady rise of 0.9 to 1.0 in.

The splendid Huddersfield barogram shows some interesting details. At 2.80 is a sudden fall of about 0.006 in. with an almost immediate recovery, followed by a second fall of half the amount.

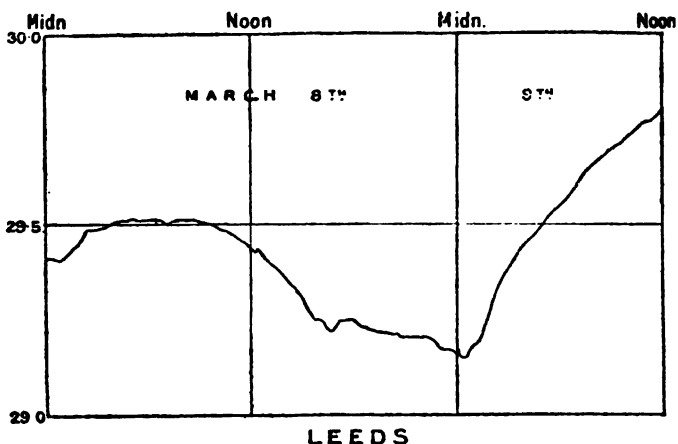


FIG. 4.

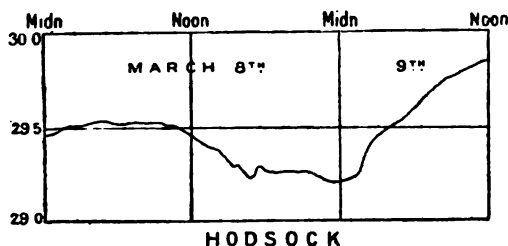


FIG. 5.

These came just an hour before the rise of 0.03 in., as was the case, too, at York very slightly later. The Worksop interval is also an hour, but comes a good hour later, or at 5 o'clock. Rev. W. C. Ley, at Lutterworth, 95 miles south of York, reports a "great jump" during the thunderstorm and violent hailstorm, which began at 5 p.m. If (which is unstated, however,) the interval between the storm and the jump was the same as at York and Huddersfield, the "jump" must have been a little after 6 o'clock, when it was "slowly clearing in the north-west." The "jump" was during a "wind swirl."

From all the data the storm seems to have stretched from North-north-east to South-south-west at least 50 miles, its northern extremity reaching rather North of York. Its line of advance, however, would seem to have been towards the South-east or South-south-east. The latter would bring its southern end over Lutterworth, and account for the heavy thunder at Driffield at $\frac{1}{2}$ of an hour later than at York. The advance may, perhaps, have followed the isobar down-curves already described.

The "whirlwind" at York resembled rather a remarkably strong squall, perpendicular to this line of advance. There are no definite signs of a real *whirl*, except that most damage was done along its southern edge; curiously, also, branches on the southern side of trees seem to have suffered worst, and any sudden accession of width came on the same side. As a fact, although Captain Key speaks of it as more violent than any wind he ever felt, its force was not very great for a real whirlwind; it nowhere levelled *everything* before it. Its capricious action is very striking. In one case, Captain Key says, a tree facing the storm was untouched, whilst one *behind* it was uprooted. Its connection with the violent cloud-changes, common in thunder-clouds, is interesting. "It appeared to me," writes Captain Key, "as if two angry thunder-clouds met over the Archbishop's Palace at Bishopthorpe (1,800 ft. South-west-by-west from his position), one coming from the South, the other from the North-west." Then "there was a sort of roar," the hut trembled, and all was over in less than a minute. Lightning flashes were noticed both before and behind in the line of the storm, and it darkened perceptibly.

At York, judging from the 2 p.m. chart, the storm was in the customary South-eastern octant of the main depression and of the minor depression as well, and occurred everywhere about an hour before the centre of the latter traversed the district. By 6 p.m. the main depression was near Glasgow, and had slightly filled up. Next morning it was at Christiania; pressure, as said, had rapidly recovered over England, where clear, cold weather prevailed, with moderate North-westerly breezes.

DISCUSSION.

Mr. MARRIOTT gave an account of the great American Tornado of March 27th (p. 187).

Mr. SYMONS said that the account of the whirlwind near York showed that the structural damage done was due to the expansion of air within the buildings as the wind passed over or near them, the barns being probably empty at this season of the year. He then made some remarks concerning American tornadoes, quoting an instance given in Ferrel's *Popular Treatise on the Wind*, illustrating the up-lifting power of these phenomena. He further said, concerning the force with which objects were hurled by the wind, that in the case of a whirlwind at Baldock he had found slates firmly embedded in the trunks of living trees.

Mr. SOUTHALL remarked that the expansion of the air theory would not apply in the case of damage to trees, which were often cut through, as if by an axe.

Mr. SYMONS said that he did not of course mean to say that all the damage done by a whirlwind or tornado was due to the expansion of the air, but that much of the damage to buildings was so caused. He could quote several instances in support of his statement, the case of a pair of houses damaged at

Walmer, in Kent,¹ being an especially good illustration of the outward force exerted by the air.

Dr. MARCET stated he was not quite prepared to accept Mr. Symons's theory that the damage caused to buildings was due to the expansion of the air inside.

Mr. TRIFF said that he had watched roofs being carried away by gales of wind, and had noticed that they were raised up and then dropped.

Mr. CLARK subsequently wrote to the Secretary:—

"In reference to the discussion on the whirlwind at York, I fancy Mr. Symons has misinterpreted the facts as to injury to barns. The mischief was done, rather, by the wind getting inside. Of course in the Dutch barn,—a roof on stilts,—there could be no outward pressure of the kind supposed.

"In reading Mr. H. A. Hazen's interesting papers on Tornadoes, now appearing in *Science*, I have been struck by numerous points of resemblance, this being indeed a tornado in miniature. Among these are (1) the meeting of two clouds to the South-west-by-west; (2) the overpowering roar, deadening the crash of falling trees; (3) the definite and narrow limits of width; (4) the rapidity of passage; (5) the association with a thunderstorm; (6) the position (as with most thunderstorms) in the South-east octant of the depression; (7) the absence of any *conclusive* proof of a true *whirl*; (8) the absence of any barographic sign of a sudden decrease of pressure. Possibly, also, the destruction of the windmill at Heckington, 70 miles South-east of York, and the distance of the main depression, 800 miles North-west, may be no accidental coincidences, with 'an hour or so later, another line . . . about 50 miles South-east of the first,' which itself develops 'two hundred to four hundred miles to the South-east of the centre of the general storm' (*Science*, XV. p. 270)."

On the possibility of Forecasting the Weather by means of Monthly Averages.

By A. E. WATSON, B.A., F.R.Met.Soc.

(Abstract.)

[Read April 16th, 1890.]

MR. WATSON's idea in this paper is that the average values of meteorological phenomena are constant quantities, and that any variation from them is sure to be met by a compensating variation in the opposite direction.

The author has got out the averages for monthly mean temperature and rainfall for Croydon for 25 years, and has tabulated the divergence of each year from this average value in two columns, + and -. He finds that the number of + and - values is nearly equal, but not exactly so.

He then goes on to argue that if the deviation has been in either direction, positive or negative, for a number of years, the probability of a reversal of the sign of the deviation increases. He says: "The reverses will be of greater importance in proportion to the number of similar signs that have characterised this series of months," and he quotes instances.

His forecasts have been published in the two best local papers for some months, and the author declares himself to be highly satisfied with the results, some of which are detailed in the paper.

¹ *Meteorological Magazine*, Vol. XIII. (1878), p. 149.

DISCUSSION.

Mr. ROSTRON remarked that the last five Februarys have been abnormally cold, but immediately before that period they were abnormally warm. If the cold Februarys continued for some years they would of course restore the mean, but the question was how long would this reaction go on?

APPLICATION OF PHOTOGRAPHY TO METEOROLOGY.

Eleventh Annual Exhibition of Instruments,

Held, by permission of the Council of the Institution of Civil Engineers, at
25 Great George Street, Westminster, S.W.

MARCH 18TH to 21ST, 1890.

PHOTOGRAPHIC METEOROLOGICAL INSTRUMENTS.

1. **Specimens of the Thermometer Tubes used in the Kew Pattern Thermograph**, and described in the *Report of the Meteorological Council of the Royal Society* for 1867. *Exhibited by the METEOROLOGICAL COUNCIL.*
2. **Scale and reading glasses for tabulating Barograms.**
Exhibited by the METEOROLOGICAL COUNCIL.
3. **Scale for tabulating Thermograms.**
Exhibited by the METEOROLOGICAL COUNCIL.
4. **Chemical Photometer devised by Sir H. Roscoe, M.P., F.R.S.** By means of this instrument a strip of paper is so exposed to daylight that the time requisite to produce a definite chemical effect can be calculated to seconds. The exposure of the paper is effected by pasting pieces of standard sensitive paper upon a band, and inserting this into a thin metal slide having a small opening at the top furnished with a cover, which can be made instantly to open or close the hole under which the sensitive paper is placed. (First Pattern, 1863.)
Exhibited by THE KEW COMMITTEE.
5. **Experimental Instrument for Recording the Intensity of Daylight**, the results being obtained by causing a disc of sensitized paper to revolve behind a screen with a rectangular aperture. *Exhibited by J. B. JORDAN.*
6. **Jordan's Sunshine Recorder.** First Pattern (March 1885.) This instrument consists of a cylindrical box, on the inside of which is placed a slip of cyanotype paper. Sunlight being admitted into this box by three small apertures, is received on the paper, and travelling over it by reason of the earth's rotation, leaves a distinct trace of chemical action.
Exhibited by J. B. JORDAN.
7. **Jordan's Sunshine Recorder.** Improved pattern. (November 1885.) In this instrument two apertures are used instead of three.
Exhibited by J. B. JORDAN.

8. **Jordan's Sunshine Recorder.** New pattern. (March 1888.) The improvement in this instrument over the others consists in using two hemi-cylindrical boxes, one to contain the morning and the other the afternoon record. An aperture for admitting the beam of sunlight is placed in the centre of the rectangular side of each box, so that the length of the beam within the chamber is the radius of the cylindrical surface on which it is projected; its path therefore follows a straight line on the paper at all seasons. The hemi-cylinders are placed with their diametral planes at an angle of 60° . *Exhibited by J. B. JORDAN.*
9. **McLeod's Sunshine Recorder.** This instrument consists of a glass sphere, silvered inside and placed before the lens of a camera, the axis of the instrument being placed parallel to the polar axis of the earth. The light from the sun is reflected from the sphere, and some of it, passing through the lens, forms an image on a piece of prepared paper within the camera. In consequence of the rotation of the earth, the image describes the arc of a circle on the paper, and when the sun is obscured this arc is broken. *Exhibited by THE KEW COMMITTEE.*
10. **Photo-Nephograph designed by Captain Abney, F.R.S.,** for the Meteorological Council, for the registration of the velocity and direction of motion of clouds. *See Reports of the Meteorological Council for the years 1879 and 1881. Exhibited by the METEOROLOGICAL COUNCIL.*
11. **Slide Rule designed by Gen. Strachey, F.R.S.,** for obtaining the height and distance of clouds from the pictures yielded by the cloud cameras. *Exhibited by the METEOROLOGICAL COUNCIL.*

INSTRUMENTS NOT PREVIOUSLY EXHIBITED.

12. **Instrument for showing the velocity of the wind.** The shaft of an anemometer is connected with the shaft of the instrument, and in turning works the small centrifugal pump, thus raising the level of the mercury in the long cistern. The deflexion of the pendulum from the vertical position is proportional to the rate of turning, and thus gives a uniform scale. *Exhibited by R. W. MUNRO, F.R.Met.Soc.*
13. **Instrument for showing the pressure of the wind from a velocity anemometer.** The arrangement is the same as in the preceding instrument, but the fall of the float in the small circular cistern is proportional to the square of the velocity and therefore to the wind pressure, thus giving a scale of pressure with the divisions at uniform distances. *Exhibited by R. W. MUNRO, F.R.Met.Soc.*
14. **Trotter's Compensating Thermometer.** The bulb and scale are connected with a metal tube, which may have any length. In order to compensate for the various temperatures through which the tube passes, a second tube of equal calibre (called the compensator) runs by the side of the first; but, instead of having a bulb, it terminates in a sealed end, and is consequently affected only by the various temperatures through which it passes. The temperature is read off on the thermometer by a sliding index scale, the arrow point on the right being set to the level of fluid in the compensating tube, and the temperature being indicated on the opposite tube. *Exhibited by J. LONG.*
15. **Draper's Self-Recording Thermometer.** In this instrument a clock rotates a disc, on which is placed a chart, indicating by radiating divisions the hours of the day and days of the week, and gives by concentric circles the degrees of temperature from 20° below zero F. to 110° above. A lever provided with a pen is supported on an axis, carried by the expansion and contraction of bi-metallic strips, so that the pen which rests on the chart moves outward and inward from the centre, drawing a line on the surface of the chart, showing the temperature at any given time. *Exhibited by J. J. HICKS, F.R.Met.Soc.*

16. **Mercurial Minimum Thermometer**, with lens front.
Exhibited by J. J. HICKS, F.R.Met.Soc.
17. **Radial Scale Thermometer**.
Exhibited by J. J. HICKS, F.R.Met.Soc.
18. **Denton's Clinical Thermometer Case**, with new spring-catch. The slight strain on the spring (which forms part of the case itself) is only exerted when the lid is being put on or off, so that the spring retains its elasticity.
Exhibited by S. G. DENTON.
19. **Watkin Aneroid** in an aluminium case.
Exhibited by J. J. HICKS, F.R.Met.Soc.

MODELS.

20. **Model of the Kew Self-recording Magnetographs**. The instrument, erected in 1857, is arranged to register photographically the variation of the position of a freely suspended Magnetic needle, as well as the intensity of the Horizontal and Vertical Forces acting upon it. A full description is given in the *Report of the British Association, 1859*.
Exhibited by the KEW COMMITTEE.
21. **Working Model to show the connection between the Monsoons and the currents of the Arabian Sea and the Bay of Bengal**.
Exhibited by A. W. CLAYDEN, M.A., F.R.Met.Soc.
22. **Model of whirling machine used at Hershram for testing anemometers and for experiments on wind pressure**. Scale $\frac{1}{4}$ inch to the foot.
Exhibited by W. H. DINES, B.A., F.R.Met.Soc.
23. **Model showing manner in which the pair of Photo-Nephographs are mounted for use**.
Exhibited by the METEOROLOGICAL COUNCIL.

PHOTOGRAPHS AND DRAWINGS OF INSTRUMENTS, &c.

24. **Description of Mr. T. B. Jordan's mode of photographically registering the indications of Meteorological Instruments**. (*Report of the Royal Cornwall Polytechnic Society, 1838.*)
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.
25. **Brooke's Photographic Self-Registering Magnetic and Meteorological Apparatus**. Description and illustrations.
Exhibited by W. MARRIOTT, F.R.Met.Soc.
26. **Drawings of the Kew pattern Barograph and Thermograph**.
 1. Barograph. Cover removed.
 2. Thermograph. Indoor arrangement.
 3. Thermograph. Outdoor arrangement.*Exhibited by C. H. THOMPSON.*
27. **Frame containing early autographic records of Magnetograph and Barograph** by the Daguerreotype process obtained at the Kew Observatory in 1849.
Exhibited by the KEW COMMITTEE.
28. **Frame showing various early autographic records obtained at the Kew Observatory**.
Exhibited by the KEW COMMITTEE.
29. **Engraved Copy of Photographic Record of Dry Bulb and Wet Bulb Thermometers by Old Thermograph on February 16, 1849**.
Exhibited by W. H. M. CHRISTIE, F.R.S., Astronomer Royal.

30. **Photographic Record of Dry Bulb and Wet Bulb Thermometers by New Thermograph on October 13-14, 1889.**
Exhibited by W. H. M. CHRISTIE, F.R.S., Astronomer Royal.
31. **Three photographic views of the new Thermograph.**
Exhibited by W. H. M. CHRISTIE, F.R.S., Astronomer Royal.
32. **Photographic Record of Barometer on September 2-3, 1889.**
Exhibited by W. H. M. CHRISTIE, F.R.S., Astronomer Royal.
33. **Photographic Record of Atmospheric Electricity by Thomson's Electrometer on March 16-17 and July 11-12, 1889, and on February 23-24, and March 4-5, 1890.**
Exhibited by W. H. M. CHRISTIE, F.R.S., Astronomer Royal.
34. **Four Photographic views showing the positions of Meteorological Instruments at the Royal Observatory, Greenwich, 1890.**
Exhibited by E. E. MCCLELLAN.
35. **Photographic Barograms showing the barometric oscillation due to the Krakatoa eruption, August, 1883. The stations shown are Bombay, Mauritius, Aberdeen, Valencia, Toronto, and Melbourne.**
Exhibited by the METEOROLOGICAL COUNCIL.
36. **Selection of Barograms and Thermograms.**
 1. Passage of depressions or storm centres.
 2. Sudden Changes of Temperature.
 3. Changes of Temperature and Pressure during a Thunderstorm at Kew, at 4 p.m. May 8th, 1871.
 4. Thermogram. A Summer's day. Kew, August 13th, 1876. Difference between dry and wet at 5 a.m., $0^{\circ}5$; at 2 p.m., $22^{\circ}7$.
 5. Thermogram, showing remarkable variations of hygrometric conditions, Aberdeen, August 12th, 1878. Difference between dry and wet at 2 p.m., $8^{\circ}9$; 3 p.m., $4^{\circ}6$; 4 p.m., $4^{\circ}3$; and 5 p.m., $10^{\circ}3$.
 6. Oscillation of the barometer at Falmouth, January 29th, 1889, 6 p.m., to 30th, 8 a.m. Temperature and wind direction are shown for comparison.*Exhibited by the METEOROLOGICAL COUNCIL.*
37. **Traces of the Curves from the Self-recording Instruments at the Radcliffe Observatory, Oxford, showing a remarkable disturbance on the morning of March 8th, 1889. (By permission of the Radcliffe Observer.)**
Exhibited by F. A. BELLAMY, F.R.Met.Soc.
38. **Curve showing the relation between the pressure and velocity of the wind.**
Exhibited by W. H. DINES, B.A., F.R.Met.Soc.
39. **Curve showing the normal component of the wind pressure upon a sloping surface, one foot square, the normal pressure being taken as 100, and the pressure at various angles of inclination being expressed proportionately.**
Exhibited by W. H. DINES, B.A., F.R.Met.Soc.
40. **Photographs of experimental apparatus designed for the reduction of Cloud Pictures.**
Exhibited by the KEW COMMITTEE.
41. **Photograph of the Pole Star Recorder in use at the Harvard College Observatory, U.S.A., for registering the cloudiness during the night (see p. 188).**
Exhibited by Prof. E. C. PICKERING.
42. **Photographs of Aitken's Dust Counters.**—1. Showing Mr. Aitken observing with the instrument for use about the hill outside the Ben Nevis Observatory. 2. Instrument for use inside the Observatory, with tubes connecting it with the free atmosphere.
Exhibited by A. BUCHAN, M.A., F.R.S.E.
43. **Two Albums containing the Photographs of the Stations of the Royal Meteorological Society, taken by Mr. W. Marriott during the inspections, 1884-1889.** *Exhibited by the ROYAL METEOROLOGICAL SOCIETY.*

44. **New England Meteorological Society's Exhibition, January 1889.** Two Views.
Exhibited by A. L. ROTCH, F.R.Met.Soc.
45. **Photograph taken from the Sydney Observatory,** showing the thermometer shed, evaporator, solar thermometer, &c., in foreground.
Exhibited by H. C. RUSSELL, B.A., F.R.S.
46. **The Seismograph in use at the Sydney Observatory, New South Wales.**
Exhibited by H. C. RUSSELL, B.A., F.R.S.
47. **Diagrams showing the rise and fall of the Tides on the River Thames** from February 24th to March 3rd, 1890, as recorded by Adie's Tide Gauge at North Woolwich and Deptford. The unusual tide on February 28th rose $2\frac{1}{2}$ hours before its time, then fell, and 2 hours after rose again.
Exhibited by P. ADIE.
48. **View taken at the Meglis Alp on the way to the Sântis Observatory, Switzerland, September 7th, 1888.**
Exhibited by R. H. SCOTT, M.A., F.R.S.
49. **Map of the Environs of Sion House in 1635.** The present Kew Observatory is erected on a part of the area. *Exhibited by F. GALTON, F.R.S.*

PHOTOGRAPHS OF METEOROLOGICAL PHENOMENA, &c.

50. **Photographic Scale showing Intensity of Sunlight during Solar Eclipses, July 18th, 1860.**
Exhibited by G. J. SYMONS, F.R.S.
51. **Photographs of Clouds taken at the Observatory, Boulogne sur Seine France.**
Exhibited by MONS. PAUL GARNIER.
52. **Photographs of Clouds taken at the Specula Vaticana, Rome.**
Exhibited by PADRE F. DENZA.
53. **Photographs of Clouds.** *Exhibited by A. W. CLAYDEN, M.A., F.R.Met.Soc.*
54. **Photographs of Cirrus Cloud reflected from the surface of the Lake of Sarnen, August 1888.**
Exhibited by DR. A. RIGGENBACH.
55. **Thunder Clouds, Northamptonshire, July 1897.**
Exhibited by DR. DREWITT.
56. **Photograph taken at Sea.** Strato-cumulus cloud in front of full moon. This illustrates the frequent error of artists drawing the moon to subtend an angle of arc larger than in Nature.
Exhibited by DR. J. L. GREEN, F.R.Met.Soc.
57. **Photographs of Fog, taken from the top of the Worcestershire Beacon,** above the general level of the fog, which covered the whole of the surrounding country, January 12th, 1888.
Exhibited by Messrs. NORMAN MAY AND CO.
58. **Sunset as seen from the Summit of Ben Nevis.**
Exhibited by G. J. SYMONS, F.R.S.
59. **Clouds, Alvona Bay, Dalmatia, September 29th, 1889.** The mountains range from 3,000 to 6,000 feet.
Exhibited by C. HARRISON.
60. **Sunsets at Mitcham.** Two views.
Exhibited by K. MCKEAN.
61. **Frame containing specimens of Cloud photographs and Sun pictures.**
Exhibited by the KEW COMMITTEE.
62. **Photograph and Enlargement of Cumulus Cloud, taken by Mr. W. Friese Greene at Bath.**
Exhibited by G. T. GWILLIAM, F.R.Met.Soc.
63. **The Tail of an ordinary Cyclone.** Photograph taken at the Sydney Observatory, New South Wales.
Exhibited by H. C. RUSSELL, B.A., F.R.S.

64. **Tornado Cloud**, Jamestown, Dakota, June 6th, 1887. Two Views. The cloud funnel was 12 miles to the north. *Exhibited by H. P. CURTIS.*
65. **Tornado Cloud**. Taken in the storm of June 22nd, 1888, showing the spiral-shaped funnel trailing at a considerable altitude in the air at the other side of a Lake, New Hampshire. *Exhibited by H. P. CURTIS.*
66. **Photographs showing the Devastation caused by the Tornado at Rochester, Minnesota**, on August 21st, 1883. *Exhibited by H. P. CURTIS.*
67. **Stereoscopic Views of the Devastation caused by the Tornado at Grinnell, Iowa**, on June 17th, 1884. *Exhibited by H. P. CURTIS.*
68. **Damage by the Tornado which passed across the Isle of Wight**, from Brightstone to Cowes, September 28th, 1876. Four views. *Exhibited by G. J. SYMONS, F.R.S.*
69. **Snow View in the Garden of the Bellerive, Zürich**. *Exhibited by W. ELLIS, F.R.Met.Soc.*
70. **Photographs of Alpine Storm and Snow Effects** taken by Mons. Gabriel Loppé. *Exhibited by G. W. FRESHFIELD, F.R.G.S.*
71. **Photograph of Snow Scene taken by Moonlight at Felton Park, Northumberland**, January 1881. *Exhibited by T. J. MURDAY.*
72. **Snow Scenes, Boston, U.S.A., Winter 1885**. Two Views. *Exhibited by H. P. CURTIS.*
73. **Ice Blockade and Frost Work**, U. S. Signal Service Station, Mount Washington, New Hampshire, during the winter of 1885. *Exhibited by H. P. CURTIS.*
74. **Photographs showing thick Rime on trees at Lincoln on January 7th, 1889**. *Exhibited by C. J. BROMHEAD, F.R.Met.Soc.*
75. **Two Photographs of Hoar-frost**. 1. Showing how the front crystals grow outwards from a branch towards the direction from which the mist has been drifting. 2. Showing how the crystals settle on the edges of leaves. *Exhibited by A. W. CLAYDEN, M.A., F.R.Met.Soc.*
76. **Hardrow Scar**. Two views: first, Summer flow; second, Winter view, January 25th, 1881. The cone at the bottom was a mass of frozen spray, firm to walk upon, but a stick could be pushed down into it. The cone was about 30 feet high. The upper part was a hollow icicle, semi-transparent, down the centre of which the water could be seen falling and passing into the cone below, which was opaque. *Exhibited by G. J. SYMONS, F.R.S.*
77. **Icicles near Aysgarth Middle Force, February 10th, 1887**. Weather very bright and cloudless, severe hoar-frost, minimum temperature 16°, no snow. *Exhibited by REV. F. W. STOW, M.A., F.R.Met.Soc.*
78. **Mill-Gill, near Askrigg, March 4th, 1889**, after several days of severe frost. Minimum temperature 11°. *Exhibited by REV. F. W. STOW, M.A., F.R.Met.Soc.*
79. **Aysgarth Vicarage, Meteorological Station, March 1890**. *Exhibited by REV. F. W. STOW, M.A., F.R.Met.Soc.*
80. **Snow Drifts at Southgate**, after the great Storm of January 18th, 1881. *Exhibited by W. MARRIOTT, F.R.Met.Soc.*
81. **Ben Nevis Observatory in Winter**. Seven views. *Exhibited by G. J. SYMONS, F.R.S.*
82. **Niagara in Winter**. *Exhibited by G. J. SYMONS, F.R.S.*

83. **Trees broken by Rime Frost, near Castle Rising, January 7th, 1889.** Three views. *Exhibited by C. B. PLOWRIGHT, F.L.S.*
84. **Photographs showing the extent of the floods on the Severn at Worcester, May 15th, 1886.** *Exhibited by G. B. WETHERALL, F.R.Met.Soc.*
85. **Photograph showing Railway Bridge between Bransford and Henwick, destroyed by the Flood on the Teme, May 14th, 1886.** *Exhibited by G. B. WETHERALL, F.R.Met.Soc.*
86. **Flood at Rotherham Railway Station, May 15th, 1886.** Two views. *Exhibited by E. M. EATON, F.R.Met.Soc.*
87. **Flood at Chelmsford, August 2nd, 1888.** Series of eleven photographs taken before 10.30 a.m. *Exhibited by G. J. SYMONS, F.R.S.*
88. **Flood at Bristol, March 9th, 1889.** Two views: Broadmead and King Street. *Exhibited by G. J. SYMONS, F.R.S.*
89. **Flood at Hereford, Midland Railway Station.** *Exhibited by G. J. SYMONS, F.R.S.*
90. **Aysgarth Force, July 26th, 1888.** There had been a heavy thunderstorm on the previous day, but the flood had considerably diminished. *Exhibited by REV. F. W. STOW, M.A., F.R.Met.Soc.*
91. **A Winter Flood.** Aysgarth Middle Force, November 28th, 1888. *Exhibited by REV. F. W. STOW, M.A., F.R.Met.Soc.*
92. **After a Thunderstorm.** Aysgarth Upper Force, June 3rd, 1889. *Exhibited by REV. F. W. STOW, M.A., F.R.Met.Soc.*
93. **Photographs of Flashes of Lightning sent to the Royal Meteorological Society since March 1889 by :—**
 Mr. H. J. Adams, Beckenham.
 Mr. A. W. Bates, Putney
 Messrs. Blanchard and Lunn, Cambridge.
 Mr. A. W. Clayden, Tulse Hill Park.
 Mr. J. R. Ellis, Cambridge.
 Mr. R. H. Gill, Woodside Park, N.
 Mr. A. Godman, St. Albans.
 Mr. E. A. Gollidge, Ilford.
 Dr. Hoffert, Ealing.
 Mr. J. F. Honeyball.
 Mr. E. E. McClellan, Greenwich.
 Mr. L. Medland, North Finchley.
 Mr. A. W. Nicholls, Peterborough.
 Mr. G. J. Ninnies, Balham.
 Mr. J. Porter, Sydenham.
 Dr. A. Riggenbach, Basle, Switzerland.
 Rev. A. Rose, Cambridge.
 Mr. A. Scrivenor, Southgate.
 Mr. E. S. Shepherd, Westbourne Grove.
 Mr. J. Stabb, Bayswater.
 Mr. R. T. Stokes, Long Ditton.
 Mr. J. L. Treadway, Crouch End, N.
 Col. Tupman, F.R.S., Blackheath.
 Prof. Weber, Berlin.
 Mr. G. M. Whipple, Richmond.
 Mr. J. W. Young, Croydon.
94. **Photographs of Electric Sparks, explaining the Formation of Dark images of Lightning flashes.** *Exhibited by A. W. CLAYDEN, M.A., F.R.Met.Soc.*
95. **Photographs of Electric Sparks illustrating Mr. Clayden's explanation of the Dark images of Lightning flashes.** *Exhibited by S. BIDWELL, F.R.S.*

96. Photographs of oak tree split by lightning, 5.30 p.m. June 6th, 1889; struck again and shivered, 1.30 p.m. June 7th, at Old Farm, Sachel Court, near Cranleigh, Surrey. Two Views.

Exhibited by CAPT. J. P. MACLEAR, F.R.Met.Soc.

G. J. SYMONS, F.R.S. } *Secretaries.*
JOHN W. TRIPE, M.D. }

WILLIAM MARRIOTT, *Assistant-Secretary.*

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

MARCH 19TH, 1890.

Ordinary Meeting.

HENRY F. BLANFORD, F.R.S., Vice-President, in the Chair.

DAVID BALFOUR, M.Inst.C.E., Myre Hall, Houghton-le-Spring;

WILLIAM BELK, M.Inst.C.E., Hartlepool;

Capt. GEORGE A. CHADDOCK, The Elms, Lea Bank Road, New Brighton;

WILLIAM SANTO CRIMP, Assoc.M.Inst.C.E., London County Council, Spring Gardens, S.W.;

GEORGE FELLOWS, Beeston Fields, Nottingham;

ARCHIBALD EDWARD GARROD, M.A., M.D., M.R.C.P., 9 Chandos Street, W; and

Capt. HERBERT E. RAWSON, 6 Cornwall Gardens, S.W.,
were balloted for and duly elected Fellows of the Society.

The following Papers were read;—

"A BRIEF NOTICE RESPECTING PHOTOGRAPHY IN RELATION TO METEOROLOGICAL WORK." By G. M. WHIPPLE, B.Sc., F.R.Met.Soc. (p. 141.)

"APPLICATION OF PHOTOGRAPHY TO METEOROLOGICAL PHENOMENA" By WILLIAM MARRIOTT, F.R.Met.Soc. (p. 146.)

On the motion of the CHAIRMAN the thanks of the Society were given to the Exhibitors for the loan of their instruments, &c.

The Meeting was then adjourned, in order to afford the Fellows an opportunity of inspecting the Exhibition of Instruments, &c., illustrating the application of Photography to Meteorology, which had been arranged in the Library of the Institution of Civil Engineers (p. 179).

APRIL 16TH, 1890.

Ordinary Meeting.

BALDWIN LATHAM, M.Inst.C.E., F.G.S., President, in the Chair.

THE MARQUIS OF GALLIDORO, Villa Gallidoro, Palermo; and

JAMES MALLET VEEVERS, Mayfield, Denton, near Manchester,
were balloted for and duly elected Fellows of the Society.

The following Papers were read:—

"THE COLD PERIOD AT THE BEGINNING OF MARCH, 1890." By CHARLES HARDING, F.R.Met.Soc. (p. 152.)

"THUNDERSTORM AND WHIRLWIND AT YORK, MARCH 8TH, 1890." By J. E. CLARK, B.A., B.Sc. (p. 169.)

"ON THE POSSIBILITY OF FORECASTING THE WEATHER BY MEANS OF MONTHLY AVERAGES." By ALBERT E. WATSON, B.A., F.R.Met.Soc. (p. 178.)

CORRESPONDENCE AND NOTES.

"THE AMERICAN TORNADO OF MARCH 27TH, 1890." By WILLIAM MARRIOTT,
F.R.Met.Soc.

THE great storm which passed over the United States and played such havoc had its origin in the Rocky Mountains somewhere near Utah, where it was first observed on the morning of March 26th. The lowest barometer reading was 29.60 ins. at Salt Lake City, surrounded by generally clear weather, except on the North and South Pacific Coast, where rain was falling. During the day the cyclone greatly increased in energy and magnitude, its influence being felt as far north as Montana, and its southern limit reached the Gulf of Mexico over Texas, snow beginning to fall in the north-west and rain to the eastward in Kansas. The wind throughout the surrounding country increased in force and blew towards the storm centre from all points at the rate of 20 to 24 miles an hour. The storm centre continued to move eastward, and by 8 a.m. on Thursday, the 27th, had reached Leavenworth, Kansas, where the barometer reading was 29.28 ins. The force of the wind for a radius of 500 miles from the centre averaged 86 miles an hour on the eastern side, and from 12 to 14 miles greater on the southern side, while on the western side the velocity was 60 miles an hour, with a severe "blizzard" raging in Nebraska and Wyoming, and a "norther" prevailing in Texas.

By noon the centre had reached the State of Illinois, the barometer reading at Springfield being as low as 29.08 ins.

At 8 p.m. the area of the storm extended from Central Minnesota to the Gulf of Mexico, and from Nebraska to Pennsylvania, with snow in Minnesota, Nebraska, Iowa, Wisconsin and Northern Ohio, while heavy rain was falling in Kansas, Illinois, Indiana, Ohio and Pennsylvania, and rapidly extending in advance of the storm centre.

While the storm was moving eastward every condition appeared favourable for the most violent local storms. The colder and very high North-west winds were setting in on the rear of the storm, causing the temperature in Kansas and Missouri to drop to within two or three degrees of the freezing point. At the same time the warmer air from the south was being drawn north to fill the vacuum occasioned by the storm centre, and the temperature as far north as Louisville standing at 66° and a little to the south at 70°, made a difference of nearly 40° in temperature in the space of only a few miles. It was the intermingling and clashing of these two air currents that formed the local tornadoes on the southern border of the storm centre.

The storm passed on from Illinois, crossing Indiana and Ohio, and at 8 a.m. on the 28th the centre was over Lake Erie, rain then falling in all the States south of the lakes to Georgia, and along the Atlantic as far north as Boston, and snow falling in Illinois, Michigan, Northern New York, Maine, and Canada, and high winds prevailed in all the States from the Mississippi Valley east to the Atlantic seaboard. During the night the storm passed away to the north-east over northern New York and Maine, out to the Atlantic.

It is reported that two tornado paths were developed, one in Southern Illinois, the other in Kentucky. The former passed south-east into Tennessee, while the latter spent its force north-east of Jeffersonville.

The tornadoes in Southern Illinois occurred between 3 and 5 p.m., while that at Louisville and Jeffersonville took place about 9 p.m. The path of the tornado, which passed through Metropolis, was 800 yards wide.

These tornadoes caused immense loss of life, destroyed towns, blew trains off the track, and left wreck and ruin in their path.

Of course the telegraphic information that has appeared in the English newspapers is very scanty, but from this we learn that in

Jackson County, Illinois, 16 persons were killed.

Grand Tower	"	6	"	"
Gallatin, Tennessee	"	4	"	"
Marion, Kentucky	"	18	"	"
Blackford	"	80	"	"
Dixon	"	8	"	"

The greatest loss of life was at Louisville, Kentucky, where the tornado passed right through the town. It is reported that at least 100 persons were killed.

An observer of the cyclone cloud, living on the north side of the Ohio, thus describes it;—

"The cloud approached through the gap in the hills below Louisville, through which the Ohio river flows. It was in the shape of a balloon, constantly rotating, and with an attenuated tail towards the earth. It emitted a constant fusillade of thunder and lightning, and seemed composed of a snakelike whirling mass of electric currents, whose light was sometimes suddenly extinguished for brief seconds, leaving a terrible darkness. The cloud made a fearful roar. It came through the gorge into the city, moved with great rapidity and with an awful rumbling sound, leaped across the river, changing the waters into white foam, and disappeared through Jeffersonville."

A lady at Rogana says:—

"Hearing the roar of the wind I stepped to the door to look out. Just as I opened the door I saw such a sight as I hope never to see again. Right in front of the house was a low-hanging terrible black cloud. It seemed to have more the appearance of a bird's nest, hung from the large or open end and swinging violently about. I saw what seemed to be trees or parts of houses, and even animals, whirled about in it. I was for a moment very much frightened, and screamed for some one to come. I cannot yet remember that it seemed to come nearer, but the next thing I knew we were without a house, and the rain was pouring down on us."

Sergeant J. P. Finley in his "Report on the character of Six Hundred Tornadoes" (*Professional Papers of the Signal Service*, No. VII.) gives some interesting information as to the frequency, distribution and characteristics of tornadoes. From this we learn that the States in which the greatest number of tornadoes occurred are Kansas, Illinois, and Missouri. Tornadoes occur most frequently in the afternoon between four and six o'clock, June being the month with the greatest frequency. The average width of the path of destruction is 1085 feet, the velocity 80 miles an hour, and the length of the track of the tornado about 28 miles.

The tornado cloud usually looks like a huge funnel, bounding along like a ball, rising and falling, or darting from one side of its path to the other. The velocity of the wind within the cloud vortex has been variously estimated at from 70 to 800 miles an hour, the average being 892 miles. This great inrush of air draws everything into the vortex, and produces a terrible deafening roar.

At the Royal Meteorological Society's Exhibition last month there was shown a very fine collection of photographs of damage caused by several tornadoes in America (p. 184). These very clearly and strikingly illustrated the destructive character of the tornadoes. The most remarkable photograph was that showing pieces of straw driven end-on into the bark of trees.

THE POLE STAR RECORDER.

(Communicated to the International Meteorological Congress at Paris in September 1889, by A. L. ROTCH, B.Sc., F.R.Met.Soc.)

AN instrument invented by Prof. Pickering, director of the Astronomical Observatory of Harvard College, has been employed at the Blue Hill Meteorological Observatory since January 1889, to register the cloudiness during the night. This consists of a telescopic objective attached to a photographic camera and directed to the Pole Star. The camera is provided with very sensitive plates, which are inserted in the evening, and a shutter worked by an alarm clock is closed before dawn. If the sky was clear during the night, the plate after development shows a circle traced by the revolution of the star around the North Pole, but if clouds passed the trail is broken.

By means of a datum point which is worked on the plate when it is exposed, and a circle divided into hours, the time during which the Pole Star shows brightly is obtained for each hour, and the complement gives the cloudiness as in the Sunshine Recorder.

Although the part of the sky photographed is only the region of the pole, yet the mean values derived from this instrument agree fairly well with eye observations embracing the whole sky, as the following table shows.

The mean cloudiness is expressed in hundredths, and the figures in parentheses give the mean of the cloudiness observed directly at the commencement and end of each hour, except for 6 a.m.

CLOUDINESS AT NIGHT AT BLUE HILL OBSERVATORY, MASS. U.S.

1889.	Hours ending													
	P.M.						A.M.							
	7.	8.	9.	10.	11.	12.	1.	2.	3.	4.	5.	6.	7.	
January	38 (42)	45 (43)	43 (43)	45 (44)	45 (47)	42 ..	45 ..	47 ..	44 ..	47 ..	51 ..	54 ..	.. (52)	
February	38 (41)	40 (40)	42 (42)	44 (45)	48 (46)	54 ..	57 ..	52 ..	47 ..	54 ..	47 ..	43 ..	.. (53)	
March .....	..	64 (61)	61 (59)	56 (57)	56 (56)	56 ..	57 ..	53 ..	55 ..	59 ..	61 ..	.. ..	.. (70)	
April .....	..	53 (58)	50 (55)	49 (55)	46 (54)	47 ..	61 ..	66 ..	64 ..	58 ..	.. ..	.. ..	.. (64)	
May .....	..	..	46 (56)	47 (53)	45 (52)	41 ..	41 ..	43 ..	51 ..	47 ..	.. ..	.. ..	.. (59)	
June .....	..	..	..	64 (65)	62 (64)	67 ..	66 ..	70 ..	68 ..	.. ..	.. ..	.. ..	.. (72)	

DR. VAN BEBBER'S "LEHRBUCH DER METEOROLOGIE FÜR STUDIERENDE."

DR. van Bebber, whose *Handbuch der ausübenden Witterungskunde* appeared a few years ago, has now brought out a Handbook of Meteorology,¹ which is intended to take a middle position between Sprung's *Lehrbuch*—which is too mathematical for ordinary use,—and Mohn's *Grundzüge*, which deals with the subject from the point of view of weather.

The present volume is certainly useful, and will long hold its own as the standard work of reference, for Schmid's book is now very antiquated. The author is generally very careful in giving his references, though a complaint of some neglect on this score has just appeared from Dr. von Bezold.

The last three chapters, which deal with weather, are particularly interesting. The illustrations are not always good, apparently old clichés have been used to swell the number of illustrations.

We notice several slips in spelling English names, e.g., Mr. John F. Campbell, of the Sunshine recorder, appears as H. P. Campbel.

Daniell's Hygrometer is figured, and is described at p. 110 as Regnault's condensing Hygrometer!! a very great instance of carelessness.

The correction of the press has been negligently done. At p. 246 Dr. van Bebber gives the following figures on Dr. Hellmann's authority for the liability of trees to be struck by lightning:—

Beech 1, Fir 155, Oak 54.

The true figures are—

Beech 1, Fir 15, Oak 54.

ON THE NOCTURNAL TEMPERATURE OF THE AIR AT DIFFERENT HEIGHTS.

HERR Julius Juhlin has recently communicated a paper on this subject² to the Royal Society of Science, Upsala, of which the following is a summary:—

1. The depression of the temperature caused by radiation from exposed thermometers is almost constant at different heights, starting from $\frac{1}{2}$ metre above the surface of the snow.

2. On fine nights in winter the temperature increases with height. The phenomenon commences two or three hours before sunset, and continues till an hour or two after sunrise.

¹ Dr. W. J. van Bebber. *Lehrbuch der Meteorologie für Studierende und zum Gebrauche in der Praxis*. Stuttgart, Ferdinand Enke. 8vo. 391 pp. With 120 cuts and 5 plates.

² "Sur la Température nocturne de l'air à différentes hauteurs." Par Julius Juhlin. *Nova Acta Reg. Soc. Sc. Ser. III.*

3. The increase of temperature with height is greater in winter than at other seasons.
4. The increase is a linear function of the temperature. The lower the temperature the greater the increase.
5. On overcast and misty nights in winter the temperatures at different heights are nearly equal.
6. The variation of temperature follows the variation of the amount of cloud very exactly.
7. A thin veil of high clouds interferes very slightly with the increase of temperature with height.
8. In winter the surface of the snow is colder than the ambient air.
9. The fact that snowy winters are characterised by severe and protracted frost, is well explained by the physical properties of snow.
10. The temperature on hills and at great heights is higher than on plains during winter nights.

RECENT PUBLICATIONS.

AMERICAN METEOROLOGICAL JOURNAL. A Monthly Review of Meteorology and Medical Climatology. April-June 1890. 8vo.

The principal original articles are:—Trombes and Tornadoes, by H. Faye (27 pp.). This is a continuation of the translation of Mons. Faye's papers.—Vifès' Laws of Recurvature, by A. H. Dutton (3 pp.). This is an examination of the truth of the laws laid down by Vifès for the recurvature of West India hurricanes. These are thus interpreted by Mr. E. Hayden:—"In June (and October) the vertex of the parabola is in about lat. 20° to 28° N; in July (and September) 27° to 29° ; and in August 80° to 82° ." Mr. Dutton has examined all the hurricanes in these months in 1887-89, and finds that out of 24 instances, only 4 recurved within the prescribed limits, and 18 did not recurve at all. This gives only 14 per cent. of the storms recurving. If only the storms which were undoubted hurricanes were taken, there would be only 81 per cent. of success for the law. Taking 82 hurricanes in these months in previous years, only 25 per cent. obeyed the law. Mr. Dutton, therefore, concludes against the law.—The International Hydrological and Climatological Congress at Paris, by A. L. Rotch (4 pp.). This is an account of the proceedings of the Congress which was held at Paris in October 1889.—State Tornado Charts, by Lieut. J. P. Finley (17 pp.). The States dealt with are Pennsylvania, New Jersey, Delaware, Maryland, Virginia and West Virginia.—Concerning Thermometers, by Prof. W. A. Rogers (9 pp.).—Weyher's Experiments on Whirlwinds, Waterspouts, Storms and revolving Spheres, by Prof. E. Mascart (12 pp.).—Laws of the distribution of Cloudiness over the surface of the globe, by L. Teisserenc de Bort (11 pp.). The author shows that in all months there is a well-marked tendency for the cloudiness to arrange itself in zones parallel to the equator. When the distribution of cloudiness is separated from the perturbations which complicate it, in order to regard only the general phenomena, there are seen to exist (a) a maximum of cloud at the equator, changing its position slightly according to the sun's declination; (b) a band of little cloud between 15° to 85° of north and south latitude; (c) a zone of clouded sky from 85° to 50° , while higher, judging by what occurs in the northern hemisphere, the sky becomes clearer towards the poles. The conditions which cause perturbations in this general distribution are the following:—1. Other things being equal, the cloudiness is much less over the continents than over the oceans; 2. Every elevated coast exposed to a prevailing sea wind gives rise to a maximum of relative cloudiness; 3. Every region covered by the sea, where a continental wind prevails, has a relative minimum of cloudiness; 4. A wind which passes from a warm region to a colder one causes an increase of cloudiness.—New England Meteorological Society (15 pp.). This is a full account of the proceedings at the Meeting of the Society on April 15th. The chief subject of discussion was "climatic changes," which were considered under two heads, viz. Secular Changes, and Supposed recent Changes in Climate.

K. SVENSKA VET.-AKAD. HANDLINGAR. Band 15, Afk. 1, No. 14. Stockholm, 1890. 8vo.

Contains:—Ueber die Einwirkung der ablenkenden Kraft der Erdrotation auf die Luftbewegung, von Nils Ekholm (51 pp.). The author summarises his conclusions as follows:—1. The vertical component of the deviation force of the earth's rotation exerts a great influence (a) in respect of the origin and maintenance of the Trade Winds and Monsoons; (b) in respect of the general air currents of the Temperate Zones, especially of the Southern, where the circumstances are more typical and simpler, as well as in the great Antarctic depression; and (c) in respect to the dissymetry of the different winds in cyclones both in the Torrid Zone and in high latitudes, and both for the lower and the upper currents of air. 2. That the horizontal component of deviation produced by the vertical component of velocity of the air cannot be devoid of importance for the upper currents, especially in tropical cyclones, although no accurate observations are available to test the theory. He concludes by expressing the hope that accurate observations of upper currents may ultimately furnish facts to support his theory.

METEOROLOGISCHE ZEITSCHRIFT. Redigirt von Dr. J. HANN und Dr. W. KÖPFEN. April-June 1890. 4to.

The principal articles are: Der Sturm vom 11 bis 14 März 1888 an der atlantischen Küste der Vereinigten Staaten: von Dr. W. J. van Bebbber (6 pp.). This is an account of the great Blizzard which Mr. E. Hayden has described.—Ueber die Beziehungen zwischen dem Wasserstand eines Stromes, der Wasserführung desselben und der Niederschlagsabhöhe im zugehörigen Stromgebiet: von Dr. W. Ule (6 pp.). This is a paper of considerable interest to engineers. The author shows by very careful measurements on the Saale how very unsafe it is to base any calculations as to the general rainfall from the condition of the river, either as to level or quantity of water. The following figures prove this; they are all percentages, and are differences from the 15 year mean:—

	1872-76.	1876-81.	1882-86.
River-level ...	—10·6	+ 9·8	+1·4
Rainfall ...	— 5·2	+ 0·2	+5·1
Quantity of water	—14·8	+12·8	+1·9

There is no relation between these figures.—Ueber die Theorien des allgemeinen Windsystems der Erde, mit besonderer Rücksicht auf den Antipassat: von A. Sprung (17 pp.). This is a summary and comparison of the theories of Werner von Siemens and of Ferrel. He states the following result of his discussion: If a body of the mass $m=1$, which rotates on the earth's surface in latitude ϕ , with a relative velocity without friction from west to east of v , is to be transferred to another latitude ϕ , an external force must be applied in a meridional direction, which when the displacement is uniform is exactly equal to the gain of the body in *vis viva* of the relative velocity of rotation. This increase in *vis viva* follows a regular law. In the special case that the body is originally in a condition of relative rest, this expression takes a simpler form. The gain in *vis viva* of the relative velocity of rotation is always positive, so that whether the displacement is toward lower or higher latitudes, an external force must always be applied.—Die Dauer der Schneedecke im Bereiche des sächsischen Erzgebirges: von Dr. O. Birkner (5 pp.). This is a discussion of six years' observations of the duration of snow in the Erzgebirge. The increase in duration does not correspond with increase in elevation.—Resultate der meteorologischen Beobachtungen an der finnländischen internationalen Polar station: von J. Hann (16 pp.). There are three notices of Sodankylä in Lapland, of Nova Zembla, and of Seesgätyr, at the mouth of the Lena. At the last-named station the observations were continued for 22 months. Dr. Bunge tells of an extraordinary rodent (the Tarbagan *Arctomys*) which is dormant for eight or nine months while the snow is on the ground, and consequently only lives actively for three months in the year. He also says that he himself suffered much more from cold in summer than in winter, when the temperature ranged about -50°C . He occasionally stood in his shirt in the open air at such a temperature without harm.

RESULTS OF RAIN, RIVER, AND EVAPORATION OBSERVATIONS MADE IN NEW SOUTH WALES DURING 1888: H. C. RUSSELL, B.A., F.R.S., Government Astronomer. 8vo. 1889. 144 pp. and 2 plates.

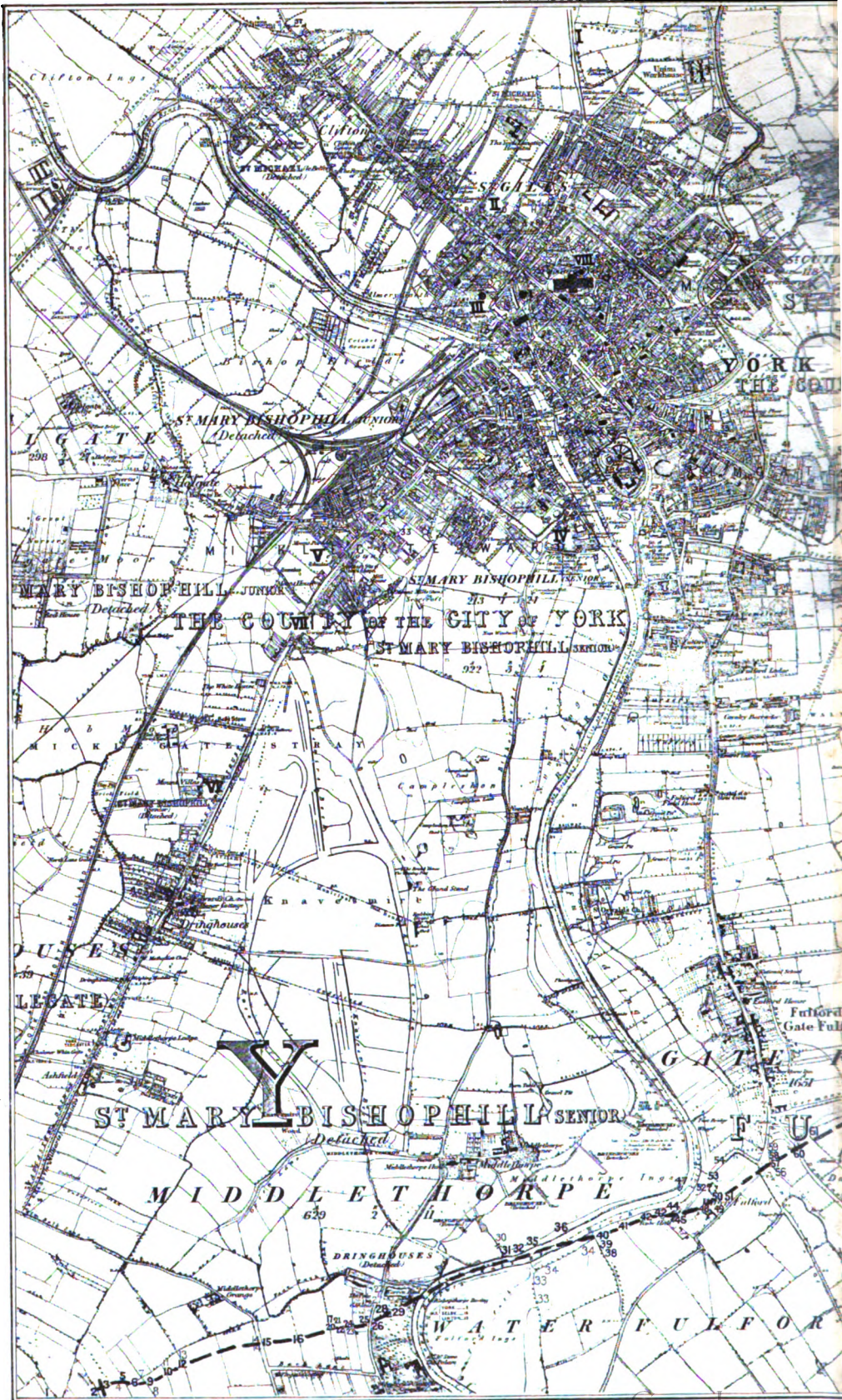
The year 1888 stands out conspicuously as the driest year upon record, and in striking contrast with 1887, the wettest on record. The remarks from nearly all parts of the Colony present the intensity of the drought, the only mitigation of which was that it followed immediately upon an abundant rainfall, which left the country charged with water in soil, rivers, and springs, as well as the abundant grasses which had resulted from such a season. In some places it would appear that 1865 was, if anything, worse than 1888, but the bulk of the evidence goes to show that, generally over the colony, 1888 was the driest year since the settlement of the country. And there are some facts which go a long way towards proving that there has been no such drought before for fifty years. In the neighbourhood of Narandera the total fall for the year was only 8 inches, not one-half of the average, and no rain sufficiently heavy to run on the surface fell between the end of October 1887 and the end of 1888. So intense was the drought there, that the native trees on the hills were all in a dying state, and over large areas absolutely dead, a state of matters which it was evident from the age of the trees killed could not have been experienced within the last fifty years. Generally, the remarks show that it was the driest year on record, experience in some cases extending over thirty years, and in other cases to the first settlement of the country about the Bland. When the break came in the weather in December, terrific thunder and hail storms occurred in many places, especially in the Northern districts, and the dry grass was in many places set on fire by the intensity of the lightning flashes. Taking the average rainfall of the whole colony from all stations for 1888, it is only 13.40 ins., which is the smallest on record. The effect of the drought is seen very clearly in the river records. With all the drainage from 1887, and some rain in February, the Darling fell rapidly, and by the middle of April was at Bourke down to summer level, and there it has remained ever since. While the Murray, at Albury, has not risen more than 1 ft. or 2 ft. by any rainfall during the year until June, and then only rose 5 ft.; there was a slight rise in July, another in the beginning of September, and the highest of the year (10 ft.) at the end of that month. Since then it has gone gradually down. Swamps in the Port Stephens district that have never been dry before, within the knowledge of black or white men, dried up during the year; and the Narran Lake at the end of the year was a dry plain, with wild fowl lying dead all about it.

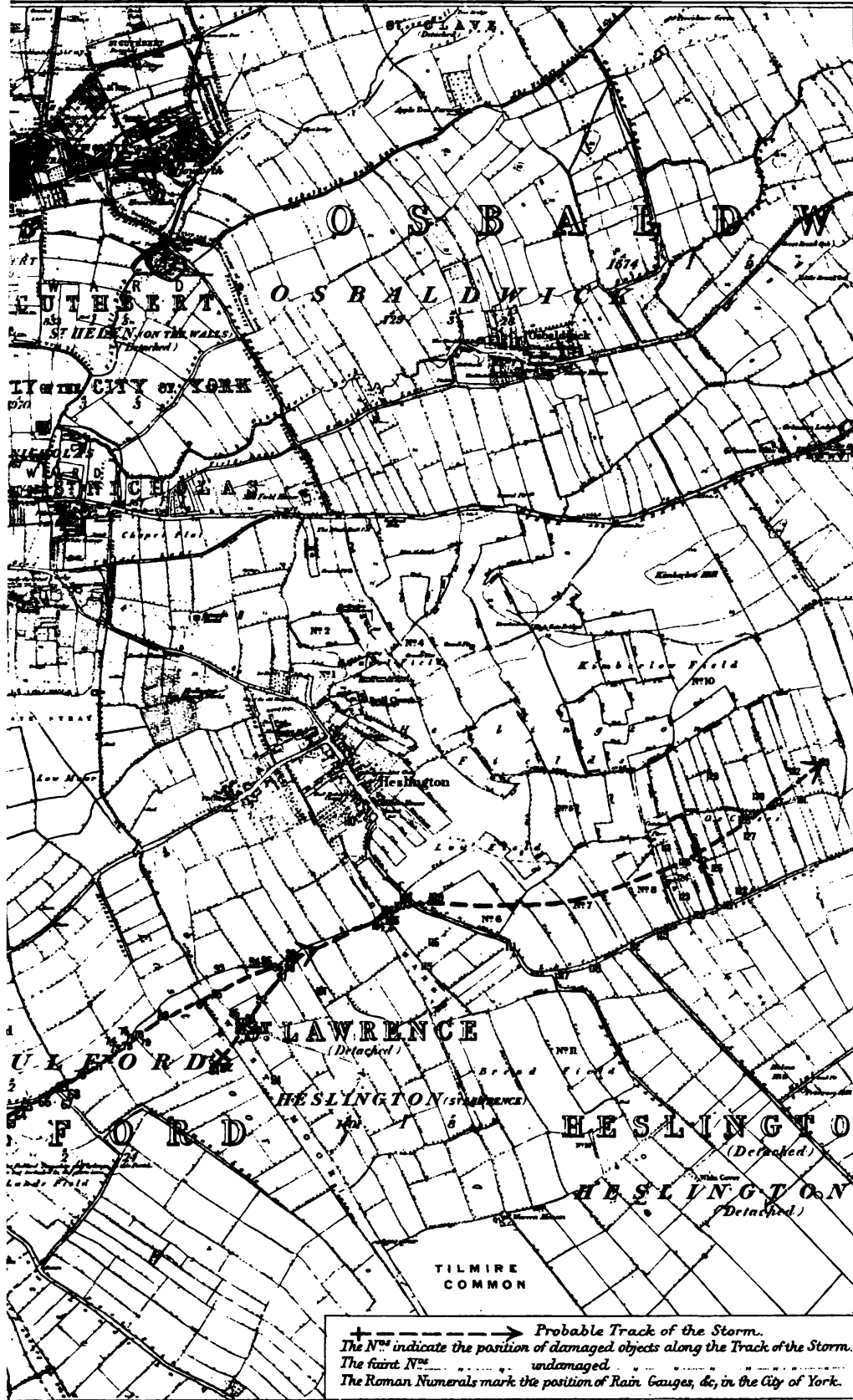
SYMONS'S MONTHLY METEOROLOGICAL MAGAZINE. April-June 1890. Vol. XXV. Nos. 291-298. 8vo.

The principal articles are:—Bibliography of Meteorology (8 pp.).—Pre-instrumental Meteorology (8 pp.).—Areas of Rarefaction or Depressions; by Dr. H. Muirhead, Rev. G. T. Ryves, and Rev. W. C. Ley (5 pp.).—Great rainfall at Hong Kong, May 29th and 30th, 1889 (5 pp.).—Anemometers, and damage by gales of wind; by W. J. Black (2 pp.).—Cycles of drought and good seasons in Africa; by D. E. Hutchins (2 pp.).—The Great Devonshire rains of May 25th (6 pp.).—Ozone and wind (2 pp.).

THE DIOCESE OF MACKENZIE RIVER. By the RIGHT REVEREND W. C. BOMPAS, D.D.

Within the space of 106 pages small octavo Bishop Bompas writes a succinct account of his diocese, the largest and least populous in Christendom. A central portion of Arctic America, it is probably for ever doomed to sterility by the severity of its climate. Upon its description, inhabitants, languages, fauna and flora, arctic life, meteorology, dress and habits, resources and prospects, interesting information is given in simple and elegant style. It is one of the few books on the Arctic Regions that is at once popular, readable, accurate, and without exaggeration. The chapters on arctic life and meteorology, in which it was so easy to make mistakes, are surprisingly free from any palpable errors, and, as bringing forward all the practical interest of the subject, are exceedingly well done.





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OF THE

ROYAL

METEOROLOGICAL

SOCIETY.

EDITED BY A
COMMITTEE OF THE COUNCIL.

OCTOBER 1890.

VOL. XVI. No. 76.

LONDON:
EDWARD STANFORD, 26 & 27 COCKSPUR ST., CHARING CROSS, S.W.;
WILLIAMS AND STRAHAN, 7 LAWRENCE LANE, CHEAPSIDE, E.C.

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Royal Meteorological Society.

ESTABLISHED 1850. INCORPORATED BY ROYAL CHARTER, 1866.

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SESSION 1890-91.

ORDINARY MEETINGS at 7 p.m.

NOVEMBER	19	1890.	MARCH	18	1891.
DECEMBER	17	,,	APRIL	15	,,
JANUARY.....	21	1891.	MAY	20	,,
FEBRUARY	18	,,	JUNE	17	,,

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QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY.

VOL. XVI.

OCTOBER 1890.

No. 76.

RAINFALL OF THE GLOBE.

COMPARATIVE CHRONOLOGICAL ACCOUNT OF SOME OF THE PRINCIPAL RECORDS.

By WILLIAM B. TRIPP, M.Inst.C.E., F.R.Met.Soc.

[Received March 31st.—Read May 21st, 1890.]

1. *Introduction.*—The Rainfall Stations contained in the Table given herewith were selected by the author on account of their suitability, as it appeared to him, to illustrate various phenomena connected with the subject of this paper; the title of which was chosen, more to show the author's aims, than to assume their successful accomplishment.

The author has endeavoured to deal principally with records coming down as nearly as possible to about the same period, and distributed as widely and evenly as possible over the earth's surface.

Such records are, as at present published, scattered throughout a number of detached reports and returns of various kinds, and the search for them has involved much expenditure of time and labour.¹

¹ The author begs to offer his acknowledgments to those who have kindly assisted him in his search, particularly to Mr. R. H. Scott, F.R.S., of the Meteorological Office, and Mr. W. Marriott of the Royal Meteorological Society, and their respective assistants, for information and aid given him with reference to the publications contained in the libraries under their charge, and also Mr. W. Ellis, F.R.A.S., of the Royal Observatory, Greenwich, and to the directors of various foreign Observatories who have kindly sent him MS. records in answer to his applications.

The author presumes that he will be expressing the opinion of all when he refers to one forcibly impressed on himself during this inquiry, as to the desirability of having rainfall records collected and tabulated in an easily accessible form, but he fears that it may be some little time before this result is accomplished.

The author considers the present attempt only in the light of a preliminary inquiry, entered upon to obtain information for himself while engaged in Hydraulic Engineering pursuits, and in the hope of throwing some light on, and in some measure assisting in, a difficult inquiry. He does not claim that this list is in any way final or complete, but the selection appeared to him to be the best that could be readily obtained, and he would be much obliged to anyone who would give him information with a view of making it more complete.

2. *General arrangement of records*.—The Northern and Southern Hemispheres, as usually shown on maps of the world published in this country, have been divided into Quadrants, as follows :—

Northern Hemisphere.				Principal Divisions.
1.	NW.	Quadrant of Eastern Hemisphere	-	Europe and Algeria.
2.	NE.	" "	-	Asia.
3.	NE.	" Western "	-	California.
4.	NW.	" "	-	U. S. America and Barbadoes.
Southern Hemisphere.				
5.	SW.	Quadrant of Eastern Hemisphere	-	Cape of Good Hope, Mauritius, &c.
6.	SE.	" "	-	Australia and Batavia.
7.	SE.	" Western "	-	New Zealand.
8.	SW.	" "	-	Buenos Ayres, &c.

8. *Parts unrepresented*.—It is evidently, however, quite impracticable to obtain suitable records of rainfall from all parts of the globe, and many parts,—such as large tracts in North America, nearly the whole of the interior of South America and Africa, the North and West of Australia, large tracts of Asia and the surface of the Ocean, and most of the Islands studding its surface,—possess either very short records or none at all.

The Western and Southern parts of Europe of course present a series of records which, for length of period of observation and completeness, cannot be approached by those of any other parts of the World, but one region in respect of which difficulty has been found in obtaining continuous records is the Southern part of France from about 1871 to 1875.

A similar series of blanks appears in most of the Indian records from about 1854 to 1860. Presumably in both these cases the deficiency is due to the disturbed state of those countries, owing to the struggles happening about those periods.

4. *Interpolation*.—Unfortunately some of the best individual records are not continuous, and in many cases the present tabular records are analysed without filling in the blanks, when these are not very serious, but where it has

been found desirable the author has filled them in from the nearest and most suitable stations he could discover; the values being altered where necessary in the ratio of the means of the years common to the records.

In some cases one record is from the earlier portion and another the later portion, the values being adjusted as above described.

Records so combined must be considered joint records, the figures so filled in, while they doubtless frequently approximately represent the true fall at both stations, being necessarily true only for the station from the records of which they were taken.

5. *Reliability of the records.*—The author has taken these generally on the authority of those by whom they were published, but correcting as far as possible clerical errors, and making the means afresh.

He has, when practicable, compared the simultaneous records of great rain-falls and droughts, and, from considerations arising out of such investigations, has formed the opinion that while the absolute amount of registered rainfall at different periods may have been affected by modes of collecting rainfall differing from the improved methods at present in use, yet that the published records indicate generally the comparative fluctuations in the relative amounts of the fall from time to time.

The records, however, present several startling features. In the record of Paris it will be found that of the 85 consecutive years, 1714-48, 2 only, 1789 and 1740, were above the mean of the 171 years recorded.

In corroboration of the truth of this we find historians recording the greatest distress as existing among the French peasantry about the middle of the century, and although this is generally attributed to political causes, yet it appears to the author possible, at any rate, that this terrible drought, which must have had such an effect on agriculture, although the records of it may have been exaggerated, may have had some effect in causing the state of things which then existed, and which was ultimately instrumental in hastening on the catastrophe of the French Revolution itself.

It is not easy to get records old enough to compare with this period, but we find that at Padua 1785-41 were much below the mean of the 161 years recorded.

The English values also, as has been pointed out by Mr. Symons, show that a drought prevailed in England at this time, the 5 years 1729-33, and the 23 years 1788-62, all but two, 1751 and 1756, were below the mean, the 13 years 1788-50 having been the driest period, and were all below the mean.

Other old records show similar droughts about the same time, while others do not do so.¹

Again, in more modern times the records of Barnaul show a period from 1852-74, 23 years, during which time only 3 years, 1856, 1868 and 1872, were

¹ It may be worth while to mention that there appears to be a tradition of a great and fatal drought both to trees and men having occurred in South Australia about the middle of last century. See H. C. Russell, "Meteorological Periodicity," *Journal of the Royal Society, N. S. Wales*, 1876; also "Egeson's Weather System," Sydney, 1889.

TABLE GIVING SOME CHIEF PARTICULARS OF RECORDS.

NORTHERN HEMISPHERE.

No.	Name of Station.	Period.		Wettest Years.		Means.	Driest Years.		Percentages.			
		First and Last Complete Years.	Total No. of Complete Years.	Date.	Inches.		Inches.	Date.	Inches.	Mean = 100.		
										Wettest.	Driest.	Wettest = 100 Driest.
N.W. Quadrant of Eastern Hemisphere.—Europe and Algeria.												
1	Edinburgh	1824	1887	64	1872	39.0	26.0	1887	13.7	150	53	35
2	Kendal	1788	1887	100	1792	83.6	52.4	1887	32.4	159	61	39
3	Ratios 100 = 30''	1726	1887	162	1852	40.8	30.0	1741	17.4	136	58	43
4	Exeter ¹	1815	1887	73	1872	46.0	30.2	1854	18.1	152	60	39
5	London ¹	1813	1887	75	1852	35.3	24.6	1858	17.3	144	70	49
6	Brussels	1823	1887	55	1878	41.2	28.6	1864	17.7	144	62	43
7	Paris	1689	1885	171	1804	27.7	19.2	1733	8.3	144	43	30
8	Geneva	1826	1885	60	1841	49.5	32.3	1832	20.7	153	64	42
9	La Rochelle	1810	1885	72	1866	50.0	25.6	1869	14.2	195	55	28
10	Toulouse	1805	1885	79	1879	36.3	25.4	1822	15.3	143	60	42
11	Lisbon	1784	1887	54	1855	51.0	28.3	1837	13.5	180	48	26
12	Oran	1841	1886	46	1870	37.1	19.1	1885	8.9	194	47	24
13	Algiers	1838	1886	49	1847	51.4	31.1	1866	19.3	165	62	38
14	Constantine	1838	1886	49	1854	42.5	24.5	1878	10.7	173	44	25
15	Palermo	1806	1887	82	1883	37.6	23.8	1866	10.8	158	45	29
16	Lico rotondo	1829	1886	58	1858	67.0	36.3	1882	17.6	185	49	26
17	Naples	1821	1887	65	1868	50.4	32.6	1880	16.0	154	49	32
18	Rome	1825	1887	63	1875	48.5	30.4	1834	12.6	160	41	26
19	Marseilles	1823	1886	64	1872	43.0	20.7	1837	10.6	208	51	24
20	Genoa	1833	1887	55	1872	108.4	51.4	1861	28.2	211	55	26
21	St. Bernard Hospice ..	1818	1885	68	1839	160.9	55.7	1857	22.9	289	41	14
22	Milan	1764	1887	124	1814	62.0	39.4	1871	25.2	157	64	41
23	Padua	1725	1887	163	1772	61.5	33.8	1822	17.8	182	53	29
24	Kremsmünster	1821	1887	67	1867	56.3	38.5	1822	22.8	146	59	41
25	Warsaw	1813	1886	69	1833	46.5	22.4	1822	14.6	208	65	31

¹ Two records combined.N.B.—In the above Table H₁ H₂ &c. mean the Highest respectively in order.

L₁ L₂ " " Lowest " " "
 W₁ W₂ " " Wettest " " "
 D₁ D₂ " " Driest " " "

All in the order given by the small figures in the Northern and Southern Hemispheres respectively.

NORTHERN HEMISPHERE.

No.	Name of Station.	Period.		Wettest Years.		Means.	Driest Years.		Percentage.			
		First and Last Complete Years.	Total No. of Complete Years.	Date.	Inches.	Inches.	Date.	Inches.	Mean = 100.		Wettest = 100 Driest.	
									Wettest.	Driest.		
N.W. Quadrant of Eastern Hemisphere.—Europe and Algeria. Continued.												
26	Upsala	1836 1887	52	1866	32.0	21.4	1875	12.2	149	57	38	
27	St. Petersburg	1836 1886	51	1864	29.3	19.1	1853	12.1	153	63	41	
28	Lugan	1838 1886	48	1842	24.4	14.8	1863	8.8	166	60	36	
29	Tiflis	1845 1886	41	1850	30.7	19.3	1856	11.3	159	58	44	
N.E. Quadrant of Eastern Hemisphere.—Asia.												
30	Katherinenberg	1836 1886	51	1846	24.4	D ₈ 14.0	1857	D ₄ 6.9	174	L ₂ 50	L ₁ 28	
31	Bogoslowak	1838 1886	48	1846	28.4	16.2	1869	5.4	175	33	19	
32	Barnaul	1838 1886	49	1839	17.7	D ₃ 10.6	1864	D ₂ 4.2	167	40	24	
33	Nertschinak	1839 1884	42	1844	25.9	16.1	1860	D ₅ 7.2	160	L ₄ 44	28	
34	Pekin	1841 1883	32	1871	41.9	W ₁ 25.4	1869	D ₉ 9.5	165	L ₃ 38	H ₂ 23	
35	Calcutta	1829 1886	58	1871	93.3	65.4	1879	43.5	143	66	47	
36	Jubbulpore	1845 1886	42	1884	94.8	53.8	1868	28.8	176	54	30	
37	Almora	1845 1886	41	1879	61.7	39.0	1860	21.9	158	L ₁ 56	L ₂ 36	
38	Agra	1845 1886	38	1873	46.5	26.6	1877	D ₁₀ 10.0	175	L ₄ 38	22	
39	Bombay	1817 1886	70	1828	122.0	W ₂ 74.0	1824	33.9	165	46	28	
40	Shimoga	1837 1886	50	1882	57.9	30.9	1843	15.3	187	50	26	
41	Bangalore	1835 1886	51	1874	56.6	35.7	1838	16.0	159	L ₅ 45	L ₄ 28	
42	Madras	1813 1886	74	1827	88.4	49.3	1832	18.4	179	37	21	
N.E. Quadrant of Western Hemisphere.—California.												
43	Sacramento	1850 1887	38	1884	34.9	19.4	1877	D ₆ 8.4	180	43	24	
44	San Francisco	1850 1885	36	1884	38.8	23.9	1877	11.9	162	50	31	
45	San Diego	1850 1885	36	1884	27.6	9.5	1863	3.0	291	32	11	
N.W. Quadrant of Western Hemisphere.—United States and Barbados.												
46	Barbados ¹	1843 1886	44	1844	78.5	W ₃ 57.8	1885	L 38.4	136	66	H 49	
47	New Orleans, &c. ¹	1836 1885	48	1846	110.6	W ₁ 57.3	1855	H ₁ 41.9	193	73	38	
48	Ft. Leavenworth ¹	1837 1885	48	1858	59.6	33.9	1843	15.9	178	48	27	
49	Cincinnati	1835 1885	48	1847	65.2	43.7	1856	25.5	149	58	39	

¹ Combined Record.

NORTHERN HEMISPHERE.

No.	Name of Station.	Period.		Wettest Years.		Meas.	Driest Years.		Percentage.			
		First and Last Complete Years.	Total No. of Complete Years.	Date.	Inches.		Inches.	Date.	Inches.	Mean = 100.		Wettest = 100 Driest.
										Wettest.	Driest.	
N.W. Quadrant of Western Hemisphere.—United States and Barbados. <i>Continued.</i>												
50	Rochester	1831	1885	53	1873	49'9	34'0	1834	22'9	147	67	H ₃ 46
51	Boston ¹	1818	1885	68	1863	67'7	44'6	1822	27'2	152	61	40
52	New Haven and New Bedford ¹	1804	1885	82	1829	58'1	42'2	1846	30'7	L ₂ 138	73	53
SOUTHERN HEMISPHERE.												
S.W. Quadrant of Eastern Hemisphere.—Cape of Good Hope, Mauritius, &c.												
53	Cape Town, R.O.	1842	1888	47	1878	41'0	25'5	1880	17'7	161	69	43
54	C. G. H. 31 stations ² } 30'5 = 33'9 ins. } 0'5 = 14'2 " }	1851	1886	36	1872	D 27'2	22'4	1865	17'0	L 121	H 76	H 62
55	Mauritius, Port Louis	1853	1886	34	1873	75'5	45'9	1866	20'7	164	45	27
S.E. Quadrant of Eastern Hemisphere.—Australia, Batavia, &c.												
56	Adelaide	1839	1886	48	1851	D ₂ 30'9	21'0	1876	D ₂ 13'4	147	64	44
57	Melbourne	1840	1886	43	1849	44'2	26'9	1865	15'9	165	59	36
58	Hobart	1841	1886	44	1863	40'7	23'4	1843	L ₂ 13'4	174	57	33
59	Sydney	1841	1886	46	1860	82'8	49'1	1849	21'5	169	44	L ₂ 26
60	Brisbane	1840	1886	36	1870	79'1	47'0	1865	24'1	168	51	31
61	Batavia	1864	1886	23	1872	W 94'4	W 74'0	1868	W 52'0	128	H ₂ 70	H ₂ 55
S.E. Quadrant of Western Hemisphere.—New Zealand.												
62	Auckland	1866	1886	21	1867	53'2	42'7	1885	28'1	125	66	53
63	Wellington	1866	1886	21	1875	65'8	52'3	1885	W ₂ 36'8	126	H ₂ 70	H ₂ 56
64	Dunedin	1866	1886	21	1886	52'6	35'5	1871	21'2	148	60	40
S.W. Quadrant of Western Hemisphere.—Buenos Ayres, &c.												
65	Buenos Ayres	1861	1888	28	1869	46'1	35'2	1861	23'0	131	65	50
66	Estancia San Juan	1867	1887	21	1883	58'8	39'5	1867	21'0	149	53	36
67	Cape San Antonio	1858	1884	27	1860	43'4	32'3	1861	20'0	H ₂ 134	62	46
68	Bahia Blanca	1860	1882	23	1876	36'0	19'2	1861	8'2	L 188	43	L 23

¹ Combined Record.² Proportional Nos. Table III. *Quart. Jour. Roy. Met. Soc.* Vol. XIV. converted from averages of 31 stations, Table I.

above the mean 1846-85. A drought extending over a considerable portion of these years is seen at the 5 stations given in Siberia and China, and also at many of the European stations there appears a tendency in the same direction.

It may, however, be remarked that over portions of the same period there was an excess in parts of the United States; the number of years above the mean of the same period at Boston was 18, and at Rochester, U.S.A., 15; the wettest years at each of these stations having occurred during the period which was so dry in Central Asia.

At the St. Bernard, 1831-49 were chiefly characterised by an excess, while at Lisbon 1836-51 there was chiefly a deficiency of rainfall.

It may be here stated that references to the mean are merely intended to indicate that the period in question had a tendency to an excess or deficiency of precipitation without any reference to the true value of that mean. It may, however, be remarked that some of the facts which have come under the author's notice would tend to prevent him from placing too much confidence in taking as a true mean at different stations exactly the same years at each, particularly for short periods. It is obvious that if there is any general sequence existing of wet and dry periods, as some assert, and if such can be found, a true mean, if such exists, should embrace a due proportion of both wet and dry years; and on the whole it appears rather likely that the truest absolute mean is that which embraces the largest number of years.

6. *Results*.—Paris has the longest record, commencing in 1689; breaks unfortunately occur, seriously diminishing the value it would otherwise possess.

Padua, beginning in 1725, and the series compiled by Mr. Symons which the author has called the "English Ratios" beginning in 1726, present facilities for comparison and combination which appear to him to be superior to those possessed by any others.

Next comes Milan, commencing in 1764.

Thus Italy, the former home of Hydraulic Engineering, has, as might be expected, a very valuable series of older records.¹

The observations at Kendal were commenced by the celebrated Dr. Dalton in 1788, and there are observations in Europe, Asia, North America, Australia, and the Cape of Good Hope, enabling 5 quadrants to be represented, however imperfectly, for the eight lustra from 1846-1885. The remaining quadrant in the Northern Hemisphere, containing California, only begins to be represented in 1851, with the exception of Sitka, of which the record is incomplete.

¹ The author has extracted comparatively little in proportion to the opportunity afforded from such mines of information as the "*Annali dell' Ufficio Centrale de Meteorologia*" of Italy; Schott's tables, published by the Smithsonian Institution of America; Dr. Wild's magnificent series, published at St. Petersburg; the *Indian Meteorological Memoirs* of Mr. Blanford, and Raulin's collections of the rainfall in France; but he has chosen a few of those which appeared to him the most perfect and those scattered over the widest area: the tendency of such records is to collect thickly round certain old-established centres of observation.

The earliest continuous record known by the author to exist in the Southern Hemisphere is that commenced at Adelaide, in Australia, in 1839. Then comes the Cape of Good Hope in 1842, and the Province of Buenos Ayres in 1858, but he has not obtained any previous to 1866 for the quadrant containing New Zealand, consequently for the four lustra 1866-85 all the quadrants can be in some measure represented by stations possessing records.

The *Magnitude* of fall in any particular year at the stations given varies from 160.9 ins. at the St. Bernard in 1839, to 3 ins. at Sandiego in California in 1868.

The value of the means, as taken in the table, varies from 74 ins. at Bombay, for the 70 years 1817-86, to 9.5 ins. at Sandiego for the 36 years 1850-85.

The table of percentages exhibits remarkable variations. Calling the means 100, the percentages of the wettest years vary in the longer records from 291 at Sandiego, and 289 at the St. Bernard, to 121 on the averages of all stations at the Cape of Good Hope, English Ratios and Barbadoes 186, and Calcutta and Toulouse each 143.

The percentages of the driest years vary from 76 on the average of the Cape of Good Hope, 73 at New Haven and New Bedford, 70 at London, down to 32 at Sandiego.

Calling the wettest year 100, the percentages of the driest years vary as follows,—excluding those which may be considered in some degree as averages, in which extremes are apt to become modified, and also the shorter records,—from London with 49 or about $\frac{1}{2}$, down to 14 or $\frac{1}{4}$ at the St. Bernard, and 11 or $\frac{1}{5}$ at Sandiego. These figures indicate the greatest range which exists at any station which has come under the author's observation.

The greater number of those stations exhibiting a very high range appear to be seaports, such as Sandiego, Genoa, Bahia Blanca, Marseilles, La Rochelle, Oran, New Orleans, Madras, &c.

Some, however, such as the St. Bernard and Warsaw, are not seaports, but the part of the coast to which Mont St. Bernard is nearest is that lying between Genoa and Marseilles, both of which stations exhibit a very high range.

It will be noticed that while the percentages due to wettest years vary from 291 to 143, with a difference of 148, those due to driest years vary only from 70 to 32, giving a difference of only 38.

The yearly values and those of periods of varying length appear to be continually rising and falling, and the above-mentioned phenomena are also often observed in comparing differences between the yearly maxima and minima, which are constantly occurring in different years of the same record, the former being frequently much greater. This shows how violent is the change due to wet years when they occur, and appears also to account for the excess in the number of years below a mean often seen in a long record; the general rule apparently being that droughts are longer continued, while wet periods are of greater intensity.

It also appears to follow as a kind of corollary to the above, that although some of the driest years often happen close to some of the very wettest, yet

that a high range of fall generally causes a high average fall at such a time, and the converse of this appears to be generally true. And when this occurs about the same time in a number of records combined as an average, the result is marked in the same way.

It also appears to the author worthy of being brought before the Society that by analysing these successive yearly maxima and minima by what he calls a comparative system, any record, so far as he has seen, can be divided into periods of varying length, the average of which often bears much resemblance to the much searched for shorter cycle. The method is as follows :—The ordinary yearly maxima and minima are called “ extremes of the first order ;” and those among these culminating points, higher or lower respectively than those on either side of them, “ extremes of the second order,” those of the second order, higher than those next them, are “ extremes of the third order,” &c.

The extremes of the first order occur on an average every 3 years in the English Ratios and in the record of Padua.

Those of the second order occur as follows in some of the larger records : —

English Ratios, Average Interval	-	Max.	9·85 years ;	Min.	9·14.
Padua	- - - - -	Max.	11·08	Min.	10·84.
Milan	- - - - -	Max.	10	Min.	9·10.
Geneva	- - - - -	Max.	9·14	Min.	7·88.
Kendal	- - - - -	Max.	7·78	Min.	10·20.
New Haven and New Bedford	- -	Max.	9·29	Min.	9·38.

Third order extremes occur in the English Ratios and Padua at intervals on an average of from 24 to 34·5 years ; the records are not long enough to determine the higher periods with advantage. These characteristic points do not always occur in the same year at different stations, except at epochs such as 1872 in Europe, when the rainfall is proportionally similar over wide areas.

The sun-spot record as given in the *Memoirs of the R. Ast. Soc.* Vol. XLIII. gives two second order extremes of maxima with intervals of 59 and 38 years ; the intervals are 35 and 46 years in the minima down to 1856.

This method is a perfectly rigid one, and can be applied to any curve of varying extremes. In the case of the rainfall curves the interval between extremes is a highly variable one.

The following is a comparison of differences between maxima and also between minima, as shown in some of the longer records :—

Year of Record.	Maxima.					Minima.					Differences.	
	Highest.	Date.	Lowest.	Date.	Difference.	Highest.	Date.	Lowest.	Date.	Difference.	Max. Greatest.	Min. Greatest.
	Ins.		Ins.		Ins.	Ins.		Ins.		Ins.	Ins.	
English Ratios	40·8	1852	19·5	1842	21·3	32·1	1881	17·4	1741	14·7	6·6	..
Padua	61·5	1772	26·4	1821	35·1	41·8	1771	17·8	1822	24·0	11·1	..
Milan	62·0	1814	36·2	1767	25·8	45·2	1844	25·2	1871	20·0	5·8	..
Geneva	49·5	1841	26·7	1821	22·8	34·8	1839	20·7	1832	14·1	8·7	..
Kendal	83·6	1792	39·5	1856	44·1	62·4	1790	32·4	1887	30·0	14·1	..
New Haven & New Bedford, U.S.A. }	58·1	1829	39·2	1816	18·9	47·2	1870	30·7	1846	16·5	2·4	..

Although, in consequence of these records embracing periods of different lengths, they cannot afford conclusive evidence, from a comparison of their extreme years, as to the existence of wet or dry periods, yet the author thought it would be of interest to ascertain the number of wettest and driest years in the tables falling respectively within the successive lustra. They are as follows :—

Wettest Years.			Driest Years.		
	No. of Years.			No. of Years.	
1772-1814	...	4	1788-41	...	2
1821-25	...	—	1821-25	...	6
1826-30	...	8	1826-30	...	—
1831-35	...	1	1831-35	...	4
1836-40	...	2	1836-40	...	8
1841-45	...	4	1841-45	...	8
1846-50	...	7	1846-50	...	1
1851-55	...	5	1851-55	...	3
1856-60	...	4	1856-60	...	7
1861-65	...	8	1861-65	...	12
1866-70	...	8	1866-70	...	9
1871-75	...	14	1871-75	...	3
1876-80	...	5	1876-80	...	6
1881-85	...	7	1881-85	...	7
1886	...	1	1887	...	2
Total No. of Records	...	68	...	...	68

The number of wettest years falling between 1866-75 = 22, and that of driest years falling between 1861 and 1870 = 21, is worthy of remark. The year 1872 has the highest number, 6, among the wettest years, then comes 1884, 4, and 1878 and 1846, 8 each. Among the driest years 1822 comes first with 5, 1861 with 4, 1864, 1865, 1866, 1869 and 1877 with 8 each.

With respect to this agreement being strongly marked over wide areas, the year 1872 is the most remarkable instance which has come under the author's observation, nearly the whole of the stations adjacent to the Western Coasts of Europe, from Upsala in Sweden to the South-west extremity of the Spanish peninsula, a range of over 2,000 miles, having been characterised in that year by a very heavy fall, which extended a considerable distance inland.

A similar state of things prevailed also in the Cape Colony in the same year, as has been elsewhere pointed out by the author.

It is somewhat curious that just a century before that a tremendous rainfall appears to have occurred. 1772 was much the wettest recorded year at Padua, and Raulin has published records from which it appears that this was also the wettest year at Marseilles. In the English Ratios the wettest 3 years of the series culminated in 1775, and from Raulin's records it appears that the state of things in the neighbourhood of Amsterdam was very similar. In 1884 the highest recorded fall took place simultaneously at each of the 8

Californian stations, extending over 500 miles of seaboard. 1846 was very wet at the 8 stations in Central Asia, and above the mean at 6 out of the 8 Indian stations. Other similar instances might be given.

7. *Diagrams and averages.*—The author thinks it may interest the Society to exhibit diagrams of some of the principal records, and also of some numerical averages of the records of the stations subdivided in the manner shown in the table, as these have been found by the author in published records, with the necessary interpolations supplied, each average consisting of complete records extending over the same periods of time respectively.

These appear to indicate that there was an average excess of rainfall at the stations given, occurring as follows :—

In the Northern Hemisphere, at the European stations in 1872 and 1888-89; Asia in 1846, 1874 and 1884; California 1884 and 1862; Sitka, in Alaska, in 1844; the United States and Barbadoes in 1878 and 1846. The highest average for the stations representing the Northern quadrant being that for 1878.

In the Southern Hemisphere, the stations of the Cape of Good Hope and Mauritius had an average excess in 1872, 1878, 1874, 1878 and other years;¹ those of Australia and Batavia in 1870 and 1872; New Zealand 1875; Buenos Ayres 1878 and 1888; Rio Janeiro, the highest 5 years average being 1881-85. (See *Met. Zeit.* June 1889, E. A. Göldi.)

Combining the Stations in the Northern and Southern Hemispheres the highest recent averages were for the years 1879, 1888 or 1878.

An average deficiency appears as follows :—

In the Northern Hemisphere, at the European stations in 1849, 1861, 1868 and 1854; at those of Asia in 1860, 1855, 1857; California in 1877 and 1868; Sitka in 1872 and 1861; U.S.A. and Barbadoes 1885 and 1854. The lowest averages being those for 1854 and 1868.

In the Southern Hemisphere the records are not so complete for the earlier years; as far as they go, the average is lowest for the Cape of Good Hope and Mauritius stations in 1866, 1865 and 1880; in Australia and Batavia in 1865, 1868, 1881 and 1854; New Zealand 1885, 1881 and 1866; Buenos Ayres 1861. The lowest general average being 1861.

Combining the stations of the Northern and Southern Hemispheres the lowest averages are for 1854 and 1861.

The regular nature of the curves between the chief maximum culminations in the longer averages of the Northern Hemisphere is worthy of remark.

Thus the more recent highest averages are contained within the 15 years from 1870-84, and the lowest in the 18 years from 1849-66. And it is somewhat remarkable that the most recent maximum rainfall culminations in Europe should occur about 1888-9 and 1872. in a very similar manner with the appearance of the more important recent maxima of sunspots of 1887

¹ Taking South Africa alone, 1872 was on the average the wettest in all parts; 1874 was the wettest in the eastern provinces and Natal; 1876 the wettest in the eastern provinces alone; and 1878 the wettest in the Cape Peninsula and the west.

and 1870, both being about 88 years apart, and that the sunspot minimum of 1856 should nearly coincide with the corresponding rainfall minimum period, the above being sunspot culminations of the second order.

A similar comparative culmination of sunspot maxima occurred in 1778, approximately about the time of the extraordinary excess of European rainfall described above.

It must be remarked that there never appears to be an absolute excess or deficiency in any year at all the stations. On the contrary, the difficulty is to find a few stations together with a similarly proportioned rainfall.

The resulting figures tend rather to indicate whether similar changes appear at standard stations in different parts than to settle the absolute quantity of rain falling on the globe in any particular year. At the same time, so far as the evidence of the stations goes, it appears that the average is higher at certain periods than at others. The author wishes, however, to guard himself against assuming that similar changes necessarily go on over the areas lying between the stations; and he wishes to refer to averages for periods within tolerably wide limits rather than to the values for particular years, and he thinks that such periods appear to display a somewhat symmetrical variation in different parts of the globe, though the characteristics of some years are more developed at certain stations than at others.

DISCUSSION.

Mr. HURCHINS said that nearly all the periods of excess of rainfall quoted by Mr. Tripp corresponded with the cyclical periods of heavy rainfall in Cape Colony, the only two exceptions being 1844 and 1846. The periods of drought also coincided very closely with the South African rainfall cycles, there being but five exceptions out of a total of nineteen periods, and these five were not entire exceptions. As regards sunspots and seasons, Mr. Tripp's maximum rainfall periods would be found to correspond more closely with Dr. Wolff's cycle of 11.11 years than with sunspots as observed. This, as he had shown elsewhere, was one of the most remarkable features in the regular rainfall of Cape Town.

Dr. TRIPE drew attention to the great difference in the elevation of some of the stations. He thought that the variation between the records of stations not very far removed from one another, for example, Genoa, Marseilles, and the St. Bernard, seemed unaccountable, except it was chiefly due to differences in elevation.

Mr. SYMONS considered Mr. Tripp's rainfall table was most valuable, especially as showing the relation between extremes and means. As regarded Dr. Wolff's sun-spot cycle figures, he would much like to know from what epoch the 11.11 year period was supposed to be calculated.

Mr. TRIPP (in reply) said that he had been interested in noting, in papers written on the subject, great similarity in dates of culmination with those in his paper, not only in South Africa, but in different parts of the globe, but he did not consider that speaking of the 11.11 year period of sun-spots was quite accurate, as the intervals between the successive culminations varied from 8 to 16 years, and, so far as he could see, it certainly did not seem that any particular period was established to within a few years, except as an average year of precipitation at the St. Bernard; and it was also the wettest recorded at Barnaul. He considered that the division into years sometimes interfered with the due recording of culminations, but some division of time must be taken, and he had therefore adopted the usual one. He had not given the elevation of the stations, because the places were well-known. It was remarkable that the three stations, Marseilles, Genoa, and the St. Bernard, each had a great range of rainfall.

Mr. ELLIS remarked in regard to the sun-spot question, that Wolff discussed the observations of sun-spots through a great number of years, and determined therefrom the epochs of maximum and minimum. He found the average period to be 11.11 years, but with considerable irregularity in the recurrence of the individual epochs, some being much accelerated, and some much retarded, as compared with the average. We cannot take any particular epoch and carry it backwards and forwards by 11.11 years, or its multiples, and consider that such, as it were, fictitious epochs can supersede, or be in any way preferable to those deduced directly from observation, and he was surprised to hear that periods of excessive rainfall were thought to fall in better with such epochs. The sympathetic relation existing between sun-spots and terrestrial magnetism is a thing about which there is no question, but the magnetic phenomena fall in with the sun-spot phenomena as actually observed. The irregularities in both phenomena are similar, one proof indeed of sympathetic relation. And it is only reasonable to suppose that, if any corresponding relation exists between sun-spot and meteorological phenomena, it would similarly become evident by agreement between the facts as observed.

MUTUAL INFLUENCE OF TWO PRESSURE PLATES UPON EACH OTHER,

And Comparison of the Pressures upon Small and Large Plates.

By W. H. DINES, B.A., F.R.Met.Soc.

[Received April 1st.—Read May 21st, 1890.]

IN May 1889 I communicated to the Society the result of some experiments on Wind Pressure, and some interest was excited by the fact that eight circular holes, each of 1 square inch section, bored in a foot pressure plate, did not appreciably lessen the pressure. A request was made by some of the Fellows that I would, if possible, extend the experiment, and accordingly the following experiments have been made.

Inasmuch as boring holes and covering them up with a movable shutter was found rather inconvenient, another plan was adopted. Two precisely similar strips of wood 4 feet long by 3 inches broad were obtained, and arrangements were made so that they could be mounted on the whirling machine side by side, either with the long edges in contact, thus presenting a plate 4 feet long by 6 inches broad or with an open space of any width up to 18 inches between them.

The pressure was determined in the manner described in a former paper.¹

Calling the pressure upon one of the strips taken alone, 50, the following figures show the pressures corresponding to various widths of open space between the strips:—

¹ *Quarterly Journal*, Vol. XV. p. 182.

With edges in contact	...	pressure	79
„ 1 in. apart	...	„	91
„ 2 in. „	...	„	97
„ 4 in. „	...	„	99
„ 6 in. „	...	„	100

It will be seen by these figures that the strips cease to influence each other appreciably as soon as they are separated by their own width, and also that when they are placed with a gap 1 inch wide between them, the pressure would hardly be altered by filling up the gap and making one solid plate 7 inches wide. This latter result affords a proof of the accuracy of the preceding experiment with the plate with the holes in it. The figures are based on the results of about 50 experiments.

I have also made experiments upon the effect of placing one of these strips edgewise to the wind in the neighbourhood of the other. The arrangement is shown in the following diagram, which represents a section, the wind coming from the right.

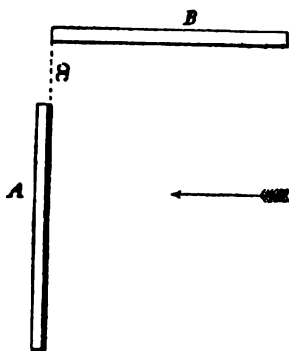


FIG. 1.

Taking 50, as before, for the pressure upon the strip A, when exposed by itself, and x as its distance from B, the pressure when B and A are in contact will be represented by 55, and on separating the strips this value seems to decrease uniformly, until when $x =$ from 9 to 10 inches, the influence of the second plate B becomes inappreciable. If we suppose the wind direction to be reversed so that B is behind A, then it (B) appears to lessen the pressure upon A when placed near it, but its influence ceases at a shorter distance and becomes inappreciable at about 4 inches. These results are based on about 40 experiments.

Turning now to the effect of the size of a pressure plate, which is a subject of considerable importance, and one on which experiments are urgently required, since it has long been a disputed question whether the pressures were proportionally greater or less upon the larger plate.

Experiments made upon the whirling machine at Hershham have led me to suppose that the greater the plate the less proportionally is the wind pressure

upon it, but it is only comparatively small plates with which experiments can be made in this way. Hence I have endeavoured to balance larger surfaces of different sizes against each other by placing them at the ends of levers of different lengths and exposing them to the natural wind. Three plates were used—the first, 6 feet by 7 feet; the second, 8 feet by 8 feet; and the third, 1 foot 6 inches by 1 foot 6 inches. The large plate, 6 feet by 7 feet, was connected with the 8 feet plate by two long thin boards placed edgewise, so that the plates, but not the boards, might catch the wind, the centres being 12 feet 9 inches apart. The two plates thus connected were then raised to the top of a pole 12 feet high, the pole forming a pivot round which they could turn, the plates being one on each side of the pole but at different distances from it. By arranging so that the larger plate might be near the pole, and the smaller one at some distance from it, it was found possible to make the wind pressure upon the smaller plate just balance the pressure upon the larger one, so that when the wind met them both perpendicularly there was no tendency for the arrangement to turn either way. This was found to be the case when the centre of the larger plate was 2 feet 9 inches from the pole and the centre of the smaller plate 10 feet.

The larger plate contains 42 square feet and the smaller 9 square feet, so that if we take 10 feet for the distance of the smaller plate from the pole, the centre of the larger plate ought to be $\frac{22}{3}$ feet, i.e. a little under 2 feet 2 inches, instead of 2 feet 9 inches. Hence this experiment shows that the pressure per square foot upon the larger plate is only 78 per cent. of that upon the smaller.

Taking the 8 feet by 8 feet, and the $1\frac{1}{2}$ feet by $1\frac{1}{2}$ feet plates, and connecting them in the same way, the corresponding distances were found to be 1 foot $4\frac{2}{3}$ inches and 4 feet $10\frac{1}{2}$ inches, giving the pressure per square foot on the larger plate as 89 per cent. of that upon the smaller.

I found a decided difficulty in adjusting the equilibrium, but that was probably due to the want of a good exposure. The plates were exposed in a level field 20 yards from trees of any kind, and 50 yards from trees above 20 feet high; the wind direction, however, was constantly shifting through an angle of 90° . Changing the distances from the pole a few inches made a marked difference in the positions taken up, so that I see no reason to doubt the accuracy of these results.

The pressures upon the edges of the connecting boards have in both instances been neglected.

It seems probable that a decrease of pressure per square foot with an increase of size may be taken as a general rule. I was led to think from the result of experiments made last year (*Quarterly Journal*, Oct. 1889) that the pressure upon a plate 6 inches in diameter was proportionately less than upon a foot plate, but I now believe that my conclusion was wrong, the greater pressure upon the foot plate being probably caused by an eddy from the frame of the apparatus used for mounting the plates. The edge of the larger plate being nearer the frame, it seems reasonable to conclude that it would be more affected than the other,

With this exception, all the experimental evidence is in favour of the rule, and I cannot help thinking that there are very few large buildings which are capable of withstanding the great pressure sometimes recorded by small pressure plates. I ought, however, to add that some of these high pressure records are perhaps due to instrumental defects.

On the Variations of Pressure caused by the Wind blowing across the Mouth of a Tube.

By W. H. DINES, B.A., F.R.Met.Soc.

[Received April 1st.—Read May 21st, 1890.]

A WHIRLING MACHINE seems to afford special facilities for experimenting with this type of anemometer, since it is easy to run a fine tube from the end of the long arm to the centre of the machine, and measure, by the difference of level of a coloured liquid in a U-shaped glass tube, placed at the centre, the variations from the normal value of the pressure, which are caused by the motion of the air across the other end of the tube.

A piece of brass tube, 1 inch diameter and 6 inches long, was obtained and mounted at the end of the long arm, so that it could point in any direction, its mouth being 28 feet from the axis of the whirler. A piece of $\frac{1}{8}$ inch composition tube, of the kind used for pneumatic bells, was brought from the brass tube to the centre of the machine and ended in a U-shaped gauge. On the machine being turned, the motion of the air across the mouth of the brass tube caused a variation of the air pressure within it, which variation being transmitted through the connecting tube, was shown on the gauge at the centre. When the machine is in motion the pressure is not transmitted to the centre without change, but is altered by the centrifugal force acting upon the air inside the tube; the difference thus caused can however be found with perfect accuracy. If a horizontal tube AB, l ft. long, filled with liquid, is turned with angular velocity ω about a vertical axis through A, there will be a difference of pressure between A and B, which will be equivalent to a head of $\frac{r\omega^2}{2g}$ ft. of the same liquid. When the tube is 28 ft. long this difference is considerable; but air being very light compared with water and the tube being full of air, it is easy to balance it by a shorter tube containing water. It will be found that the difference in pressure thus caused in a tube 1 ft. long containing water is equal to the difference in pressure caused in a tube 28 ft. long containing air, the air being taken at standard temperature and

pressure; and hence allowance for this action was obtained by making the horizontal branch of the U tube 1 ft. long.

Having found the principle of using the centrifugal force to measure wind so convenient in other experiments, I have used the same plan again here. Fig. 1 shows the arrangement which has been used. A B and C are three glass tubes containing coloured water, in communication with each other. B is fixed and placed at the centre of the whirler, but the distances of A and C from B are

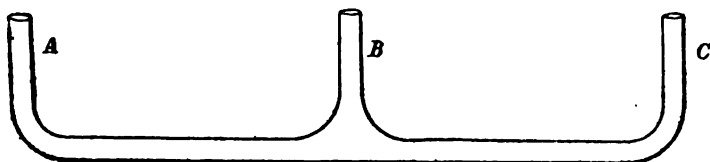


FIG. 1.

adjustable at pleasure; the communication being made in fact by flexible india-rubber tube. The pipe from the end of the long arm is connected with the top of B by an air-tight joint, and A and C are open to the air. A zero line is marked on B, and the experiments were made by adjusting the distances of A and C from B, so that rotation of the whirler caused no change in the level of the liquid in B. One pipe, either A or C, would have done, but in that case B must have been accurately placed at the centre of the whirler; using two pipes at equal distances from B a small error of this kind is eliminated. The two pipes are also convenient, because the small change in level which is almost inevitable as the machine goes round, does not of itself move the liquid from the zero mark on B. As stated above, when $A B = B C = 1$ ft., the motion does not alter the level.

The following values have been determined:—I. Brass tube vertical, so that the air blows across the mouth.

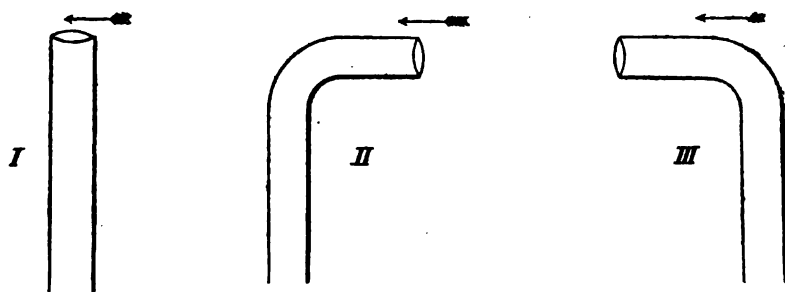


FIG. 2.

For equilibrium $A C = 35\frac{1}{2}$ inches.

A very slight inclination of the tube either way causes a decided falling off in the partial vacuum produced.

II. Tube horizontal, or air blowing straight down the mouth of the tube. For equilibrium $A C = 2$ ins.

In this position a considerable inclination, about 10° to 15° , is admissible before an appreciable change of pressure occurs.

III. Tube horizontal, but air blowing away from mouth.

For equilibrium $A C = 26$ ins.

In this position a slight change in the angle increases the vacuum produced.

To reduce these values to a difference of water level, we notice that when the velocity is 60 miles an hour, one complete turn is made in two seconds, and, therefore, $\omega = \pi$. Substituting for l in the expression $\frac{l^2 \omega^2}{2g}$ and remembering that in each case a pressure of $\frac{\omega^2}{2g}$ must be added to compensate for the effect of the centrifugal force upon the air in the connecting tube, we find that

In case I. we have a partial vacuum of 2.10 ins. of water.

„ II. „ an increase of pressure of 1.82 in. of water.

„ III. „ a partial vacuum of 0.82 in. of water.

These values refer to a velocity of 60 miles an hour; at half the pace they will only be $\frac{1}{4}$ as great; at $\frac{1}{3}$ the pace only $\frac{1}{9}$ as great, and so on, following the ordinary law with regard to wind pressure, viz. that the pressure varies as the square of the velocity.

The same values were found to hold in the case of a tube of $\frac{1}{4}$ in. diameter.

If two thin discs be placed horizontally, one a little above, and one a little below the mouth of the tube, the partial vacuum (case I.) is reduced, but the arrangement is not so susceptible to a small change of inclination as the open mouth is. With two discs, 4 ins. diameter, one $\frac{3}{8}$ in. below and the other $\frac{3}{8}$ in. above the open mouth, the partial vacuum at 60 miles an hour is 1.44 in. of water.

I have also taken the opportunity to determine the vacuum at the back of a pressure plate. With a foot plate, square, the partial vacuum close to the back at the centre is .89 in. of water at 60 miles an hour, and the increase of pressure in front at the centre is 1.82 in.; the same value which is given by the wind blowing down the tube.

The simplicity of this kind of anemometer is of great advantage; it does not seem capable of registering any low velocity, but that is a defect common to most pressure instruments, because the pressure at low velocities is so very small. For strong winds, however, it seems very suitable, and the arrangement is greatly recommended by the fact that the head can be placed in any position, however inaccessible to the daily observer, and communication made with the registering part by a long tube. According to the well-known law of Hydrostatics the tube, however long, will faithfully and immediately transmit any variation of pressure.

DISCUSSION.

Mr. LAUGHTON said that the ingenuity of Mr. Dines's apparatus had impressed him almost more deeply than even the very remarkable and valuable results which had been obtained by it. There was one point in the comparison of the pressures on plates of different sizes which appeared especially curious, the difference, namely, in the percentage of variation: it almost seemed to show that nothing can be deduced; that every result will have to be determined by independent observation. He should like to ask Mr. Dines whether the results given in the paper were to be held true for all wind forces, or whether they might be expected to vary with the strength of the wind? What had been said about the variation in the vacuum of anemometers of the Hagemann type, caused by an inclination of the tube, was a great blow to himself; a shattering of his idols, in fact. He had long cherished a hope that this type of anemometer might be adapted to use on board ship, so that the indications of a tube running up one of the masts might be read in the captain's cabin. This would now appear to be impossible; unless, indeed, it should be found practicable to have the nozzle of the tube fitted in gimbals, so as to remain always in the vertical position.

Mr. SYMONS suggested that the amount of edge in the plates used might have something to do with the results obtained; for when this factor was taken into consideration the figures appeared to follow a more regular sequence. He entirely agreed with Mr. Dines in believing that very few, if any, buildings could resist the enormous wind pressures frequently registered by anemometers.

Mr. BIRCH inquired whether Mr. Dines could state the actual pressure and velocity when the relation between the resistance caused by the various arrangements of plates was established? and over what range of velocities, if any, he thought that relation might be expected to hold good?

Mr. BUCHAN remarked on the great ingenuity of Mr. Dines's apparatus, and said that as regarded wind observations, he had never yet seen any possibility of discussing such observations except for direction only. He was much interested to find that the pressure proportionately increased as the area of the surface of the plate diminished. He described some experiments which he and Prof. Darwin had seen Mr. Dines make concerning the distribution of pressure upon surfaces placed at various angles to the wind, and stated that when the surfaces were inclined at an angle of 56° it was found that a larger pressure was obtained than when the exposure was normal.

Mr. MUNRO said that similar results to those obtained by Mr. Dines had been ascertained from the observations made at the Forth Bridge Works. Two plates were exposed, the large one being made of wood, and it was found that the pressure per foot on the larger plate was always only about half what it was on the smaller one. The great question to solve was, what was a reasonable or sufficient size for such pressure plates?

Mr. CHATTERTON inquired what was the maximum velocity which the tube arrangement of Mr. Dines could record?

Mr. SYMONS said that he believed that it was on record that when the building for the Great Exhibition of 1851 was being constructed, a wind pressure of 15 lbs. on the square foot was considered to be the greatest strain it would have to withstand.

Mr. ELLIS was glad to find that Mr. Dines was continuing his very valuable experiments, and further said that he should like to testify to the difficulty of dealing with pressure instruments as regards the registration of great pressures. In the Greenwich Osler anemometer the pressure plate was formerly connected to the recording pencil by means of a copper wire passing down the long vertical tube reaching from the anemometer to the recording table, an arrangement which he never liked, and in the year 1882 at his suggestion the copper wire was replaced by a fine brass chain, since which time the greatest pressure registered in gusts has not exceeded about 80 lbs. on the square foot, in some years 20 lbs. only or a very little more had been registered, whilst in the year 1889 the greatest pressure recorded was only 15 lbs. He did not believe in the great pressures at times registered at Greenwich previous to the year 1882, and a cautionary note in regard to these pressures was inserted in the Introduction to the Greenwich volume for 1886 and following years, as well as in the Report on the

Royal Observatory for the year 1888, which appears in the *Quarterly Journal of the Society* (Vol. XV. p. 99). He did not mean to say that greater pressures might not be experienced in the country elsewhere. It always seemed to him that the pressure plate being deflected in heavy gusts with great suddenness, the copper wire at such times acted irregularly, but the brass chain, always in tension, appeared to work more smoothly, the movements of the recording pencil better representing those of the pressure plate, whilst the action was otherwise more delicate, as was shown by the greater excellence of the register of very small pressures. For moderate pressures he considered that the record had been always fairly reliable. In the early years of the Osler record 25 lbs. on the square foot was thought to be an extreme pressure; in intermediate years greater pressures certainly became registered, but since the year 1882 there has been no further instance of apparently excessive pressure. In regard to the question by a previous speaker why the presumed effect of the copper wire was not sensible in the experiments from time to time made for determination of the pressure scale, he would remark that the hanging of a definite dead weight on to the pressure plate is a very different thing to the sudden and fierce action of the wind on the plate in heavy gusts, which could scarcely be artificially imitated.

Mr. TRIPP remarked that according to his observations of recent records of rainfall, the 'fifties' and 'sixties' appeared to have been years of absence of cyclonic disturbances, while during the 'seventies' such disturbances seemed to have been in excess. It would be interesting to know whether the curve of wind pressure for these years coincided with these inferences, as it had been remarked by Mr. Symons that there had been great differences in the estimation at different periods of the amount of allowance to be made for such pressures in buildings, and the speaker thought that these corresponded somewhat with the above observations of rainfall.

Mr. DINES said that he must thank the Society for the kind way in which they had received his paper. With regard to Mr. Laughton's question, he had noticed that the percentages between the two pairs of plates were different, and could not explain it, but he thought it would be very desirable that some one who could get a good exposure should repeat the experiments, since he had worked under considerable difficulties in that respect. He saw no reason to doubt that the relations between the pressures held for all velocities. He did not think it would be possible to use the tube form of anemometer on board ship, because the mouth of the tube being moved about by the rolling of the vessel, it would not be possible to say what proportion of the pressure or vacuum produced was due to the wind, and what was due to the rolling. It might be possible to design some form of registering apparatus which would show the small differences of pressure due to light winds, but he thought that when such slight differences as $\frac{1}{16}$ of an inch were concerned, the apparatus must be very delicate and liable to error. He agreed with Mr. Symons that an increase of the perimeter of a plate proportionally to the area did increase the pressure, but he could give no reason for such being the case. Mr. Buchan had referred to the action of the wind upon a sloping surface, and had suggested that experiments should be made upon larger surfaces. The whirling machine at Hersham would not carry much beyond a foot plate, because the larger sizes required much stronger apparatus and consequently much greater weight. Also a very powerful engine would be required. It required nearly 2-horse power to move a foot plate through the air at 60 miles an hour, apart from the long arm and supports, and the 4-horse power engine which he had at Hersham could not give a greater velocity than 50 miles an hour to the end of the whirling machine when the foot plate was used. He (Mr. Dines) had calculated that at least 150 h. p. was used by a locomotive engine running at 60 miles an hour in overcoming the air resistance upon itself apart from the tender and carriages, and he could not understand why some of this loss was not avoided, as it easily might be. Answering Dr. Tripe, he said that he did not believe that there was any peculiarity about circular plates, he thought they would follow the same rule as other shapes; in all the cases which he had tried, namely circles containing areas of $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, and 1 ft., the pressure had been nearly the same as upon square plates of the same area. Mr. Chatterton had inquired whether the tube form of anemometer would answer for high velocities; he thought it would answer admirably, and

that the rule of pressure varying as the square of the velocity might be trusted to hold for the whole range of possible wind velocities, excepting perhaps for the very lowest. Mr. Ellis had referred to the momentum of pressure plates. He believed that the high pressures recorded were mostly due to the momentum of the moving parts carrying the index beyond its proper position; and Mr. Ellis's remarks about the Greenwich anemometer had confirmed his belief. Mr. Strachan had remarked that the subject of wind pressure generally was one of mechanics, and no doubt it was so. This special branch of mechanics, however, viz. hydro-dynamics, was so difficult, and the mathematical analysis required so complicated and abstruse, that personally he could not attempt to approach the subject from that side, and he believed that it was only in a few limited cases that a rigorous mathematical solution could be obtained.

In conclusion, he should like to say that he thought the tube form of anemometer a very good one indeed, but there were two points about it which must not be overlooked. It was essentially a pressure and not a velocity instrument, and its indications of velocity would certainly depend upon the density of the air. Secondly, if the registering part be placed away from the head, as must generally be the case, the communication must be made by means of two tubes, in such a manner that the actual pressure of air in the room in which the registering part is placed cannot affect the instrument. Otherwise, the opening of a door or window, or even stirring up the fire and increasing the draught up the chimney, would appear on the record as a change of wind velocity.

On the Difference produced in the Mean Temperature derived from Daily Maximum and Minimum Readings, as depending on the time at which the Thermometers are read.

By WILLIAM ELLIS, F.R.A.S., of the Royal Observatory, Greenwich.

[Received May 17th.—Read June 18th, 1890.]

THE maximum and minimum readings of air temperature which appear in the *Greenwich Observations* are those of the maximum and minimum thermometers on the revolving stand, and refer to the civil day from midnight to midnight. When the Greenwich maximum and minimum temperatures were first communicated to the Royal Meteorological Society for insertion in the *Meteorological Record*, in the table giving results for London stations, they were supplied as thus tabulated for the Greenwich volume, and as indeed previously also appearing in the *Weekly Return* of the Registrar General. But on this arrangement, the separate daily readings were not comparable with those of the other London stations, since the latter were tabulated according to the plan adopted by the Society for stations termed "Climatological." In consequence of which the Greenwich values, since the beginning of the year 1886, have, at the request of the Society, been supplied according to the climatological plan, that is to say the reading of the

maximum thermometer for the twenty-four hours ending 9h. a.m. is entered to the preceding civil day, and the reading of the minimum to the same civil day.

Without consideration of the matter it might be supposed that, with values tabulated according to the two methods described, the monthly means of the maximum and minimum readings would, on the average, be similar on both systems. But on making the necessary comparison, a perceptible difference, almost always in the same direction, was found to exist, not only between the means of the maximum readings, but also between the means of the minimum readings. This, it appeared to me, might have sufficient interest for the Fellows of the Royal Meteorological Society to make it desirable to communicate to the Society the results of a comparison made for the four years 1886 to 1889. The differences found to exist between the two sets of means are given in Table I., from which Table II. is formed showing the differences in the mean temperature of the different months thereby produced, as derived from the mean of the maximum and minimum readings.

It will, of course, be understood that the differences given in the Tables are differences of indication of the same maximum and the same minimum thermometer (those of the revolving stand) arising simply from difference in the method of tabulation.

TABLE I.

Month.	Excess of Climatological Maximum above Civil Day Maximum.					Excess of Climatological Minimum above Civil Day Minimum.				
	1886.	1887.	1888.	1889.	Mean.	1886.	1887.	1888.	1889.	Mean.
January ..	+0.2	+0.2	+0.4	0.0	+0.20	+0.3	-0.5	-0.5	-0.4	-0.27
February ..	0.0	+0.1	0.0	+0.1	+0.05	-0.1	+0.3	+0.3	0.0	+0.13
March	0.0	+0.2	+0.4	0.0	+0.15	+0.3	+0.5	+0.5	+0.1	+0.35
April	+0.3	0.0	+0.2	+0.1	+0.15	+0.8	+0.4	+0.3	+0.3	+0.45
May	+0.2	+0.2	+0.2	0.0	+0.15	+0.7	+0.5	+0.7	+0.5	+0.60
June	+0.1	+0.2	0.0	+0.3	+0.15	+0.4	+0.5	+0.1	+0.3	+0.33
July	+0.3	0.0	+0.7	+0.1	+0.27	+0.6	+0.5	0.0	+0.3	+0.35
August	0.0	0.0	+0.3	0.0	+0.08	+0.5	+0.2	+0.9	+0.5	+0.52
September ..	+0.1	0.0	-0.1	0.0	0.00	+1.6	+0.7	+1.0	+0.9	+1.05
October	0.0	0.0	0.0	0.0	0.00	+0.6	+0.3	+0.3	+0.5	+0.42
November ..	+0.1	+0.4	-0.2	-0.1	+0.05	+0.2	+0.5	+0.4	+0.4	+0.38
December ..	+0.1	+0.3	+0.4	+0.8	+0.40	-0.1	-0.3	+0.3	-0.1	-0.05
Means	+0.12	+0.13	+0.19	+0.11	+0.14	+0.48	+0.30	+0.36	+0.28	+0.36

Examining the various columns of Table I. it is seen how persistent is the tendency to difference in one direction. Especially is this so as regards the means of the minimum readings, which not only differ more than do those of the maximum readings, but differ also by amounts that vary considerably with the time of year, being apparently greatest in spring and autumn, less in summer, and least, being indeed reversed in direction, in winter. The difference between the means of the minimum readings in the month of September is especially remarkable, particularly in the year 1886. In explanation of these differences

TABLE II.

Month.	Excess of Climatological Monthly Mean Temperature above Civil Day Monthly Mean Temperature.				
	1886.	1887.	1888.	1889.	Mean.
January	+0.25	-0.15	-0.05	-0.20	-0.04
February	-0.05	+0.20	+0.15	+0.05	+0.09
March	+0.15	+0.35	+0.45	+0.05	+0.25
April	+0.55	+0.20	+0.25	+0.20	+0.30
May	+0.45	+0.35	+0.45	+0.25	+0.37
June	+0.25	+0.35	+0.05	+0.30	+0.24
July	+0.45	+0.25	+0.35	+0.20	+0.31
August	+0.25	+0.10	+0.60	+0.25	+0.30
September	+0.85	+0.35	+0.45	+0.45	+0.52
October	+0.30	+0.15	+0.15	+0.25	+0.21
November	+0.15	+0.45	+0.10	+0.15	+0.21
December	0.00	0.00	+0.35	+0.35	+0.18
Means	+0.30	+0.22	+0.27	+0.19	+0.25

it is to be remembered, first as regards the maximum, that the daily reading for the twenty-four hours ending 9h. a.m. being, according to the climatological plan, placed to the preceding civil day, if the temperature between midnight and 9h. a.m. should in any case be higher than that for the twenty-four hours ending with midnight, the recorded climatological maximum will be higher than that for the civil day ending at midnight, and a few instances of this kind occurring during a month tend to throw up the climatological mean as compared with the civil day mean. On the other hand, as regards the minimum, if the temperature between 9h. a.m. and midnight should fall below that for the twenty-four hours ending with 9h. a.m., the minimum recorded for the civil day will be lower than that recorded on the same day on the climatological plan, and this occurring occasionally during a month tends to make the climatological mean again relatively high. So that the climatological mean maximum and minimum both become increased as compared with those given by tabulation according to the civil day. Or the mean temperature as derived from the mean of the maximum and minimum readings differs, according to the system of tabulation employed, in the way shown in Table II.

There is a converse case, both as regards maximum and minimum, not apparently occurring so frequently as the cases before mentioned, excepting in winter, and consequently generally insufficient to compensate for their influence on the mean values. For instance, the temperature may happen to be higher between midnight and 9h. a.m. than at any time during the twenty-four hours ending with the following 9h. a.m., in which case the civil day maximum would be the higher of the two. Or the temperature may be lower between 9h. a.m. and midnight than during the twenty-four hours ending with the following midnight, in which case the climatological minimum will be the lower of the two.

The anomalies mentioned arise only when the diurnal variation of

temperature is abnormal. When the daily maximum occurs at the ordinary time, in early afternoon, and the minimum shortly before sunrise, the maxima and minima, on both the systems of tabulation mentioned, would, in the absence of great fluctuations of temperature from day to day, be in this country generally similar. The cases of abnormal change first mentioned are those that more frequently occur, excepting in winter, whilst those afterwards spoken of are more especially prevalent in winter.

As respects the great difference between the means of the minimum readings in September 1886, I have gone over the numbers again, and find the difference to be really correct, and due to the instances in which the temperature before midnight fell below that of the preceding night. On one day especially, September 10th, the minimum for the twenty-four hours ending 9h. a.m. was $61^{\circ}\cdot1$, the climatological minimum for the day, but before the midnight following the temperature fell to $46^{\circ}\cdot0$, which was the minimum for the day according to civil reckoning. Thus $0^{\circ}\cdot5$ of the difference ($1^{\circ}\cdot6$) between the monthly means was produced by this one case.

It may be further pointed out, as concerns the variation between the means of the minimum readings during the course of the year (last column of Table I.) that the greatest differences occur at those periods of the year which, on the average, are most free from cloud, spring and autumn, whilst the negative differences are found during the most cloudy period, that of winter.

The tabulation of the maximum and minimum readings according to the plan adopted for Second Order stations, by which the maximum and minimum readings for the twenty-four hours ending 9h. p.m. are placed to the day of reading, seems likely to give mean values more in accordance with those found from tabulation according to the civil day, but I am not at present prepared to offer any evidence on this point.

ADDENDUM.

Reference is made in the preceding paper to the system of registering the maximum and minimum temperature adopted for stations of the Second Order (according to which they are tabulated for the twenty-four hours ending 9h. p.m.) as likely to give means more in accordance with those found from values referring to the civil day, but no evidence on the point is given. It however happens that the observations of the thermometers in a Stevenson screen and on the roof of the Magnet House at the Royal Observatory are recorded on the Second Order station plan, and as their daily readings have been compared with the corresponding readings of the ordinary maximum and minimum thermometers on the revolving stand, the monthly means of the observed differences, if applied to the monthly means of the Stevenson screen and roof thermometers, enable us to infer therefrom the monthly means of the ordinary maximum and minimum thermometers on the revolving stand according to the Second Order station system, and so

compare them with means of readings of the same thermometers applying to the civil day, midnight to midnight. In these results Sundays are omitted, the Stevenson screen and the roof thermometers not being read on Sundays, but as the question is one of differences, this does not signify, so long as the same days are used in all cases. Such results are available for the years 1886, 1887, and 1888, but not for 1889, the discussion of the work for that year not being yet complete. By the process described, apparently involved, but under the circumstances really saving labour, it will be seen that in the annexed tables we have, as before, simply differences of indication of the same maximum thermometer and the same minimum thermometer (those of the revolving stand) as depending entirely on the method of tabulation.

TABLE III.

Month.	Excess of Second Order Maximum above Civil Day Maximum.				Excess of Second Order Minimum above Civil Day Minimum.			
	1886.	1887.	1888.	Mean.	1886.	1887.	1888.	Mean.
January	+0.1	+0.2	+0.2	+0.17	+0.2	0.0	-0.2	0.00
February	-0.1	0.0	+0.2	+0.03	+0.1	+0.75	+0.35	+0.40
March	-0.1	-0.05	+0.25	+0.03	0.0	+0.3	+0.1	+0.13
April	-0.1	+0.15	0.0	+0.02	+0.3	+0.3	+0.3	+0.30
May	+0.1	0.0	+0.1	+0.07	+0.5	+0.65	+0.5	+0.55
June	+0.1	+0.05	0.0	+0.05	+0.5	+0.55	+0.1	+0.38
July	0.0	0.0	+0.05	+0.02	+0.4	+0.5	+0.2	+0.37
August	0.0	+0.05	0.0	+0.02	+0.5	0.0	+0.6	+0.37
September	0.0	0.0	0.0	0.00	+0.7	+0.6	+0.4	+0.57
October	+0.1	+0.05	0.0	+0.05	+0.1	+0.3	+0.25	+0.22
November	+0.1	+0.2	+0.2	+0.17	0.0	+0.15	+0.3	+0.15
December	+0.3	+0.45	+0.1	+0.28	-0.6	+0.2	+0.1	-0.10
Means	+0.04	+0.09	+0.09	+0.08	+0.22	+0.36	+0.25	+0.28

ROYAL OBSERVATORY, GREENWICH.

Excess of Values of Climatological Maximum, Minimum and Mean Temperature, above the corresponding Civil Day values, 1886 to 1889.

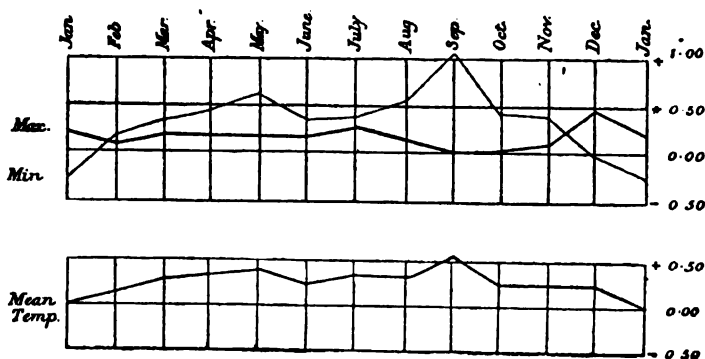


FIG. 1.

TABLE IV.

Month.	Excess of Second Order Monthly Mean Temperature above Civil Day Monthly Mean Temperature.			
	1886.	1887.	1888.	Mean.
January	+0°15	+0°10	0°00	+0°08
February	0°00	+0°38	+0°28	+0°22
March	-0°05	+0°12	+0°17	+0°08
April	+0°10	+0°23	+0°15	+0°16
May	+0°30	+0°32	+0°30	+0°31
June	+0°30	+0°30	+0°05	+0°22
July	+0°20	+0°25	+0°12	+0°19
August	+0°25	+0°02	+0°30	+0°19
September	+0°35	+0°30	+0°20	+0°28
October	+0°10	+0°18	+0°13	+0°14
November	+0°05	+0°17	+0°25	+0°16
December	-0°15	+0°33	+0°10	+0°09
Means	+0°13	+0°23	+0°17	+0°18

ROYAL OBSERVATORY, GREENWICH.

Excess of Values of Second Order Maximum, Minimum and Mean Temperature, above the corresponding Civil Day values, 1886 to 1888.

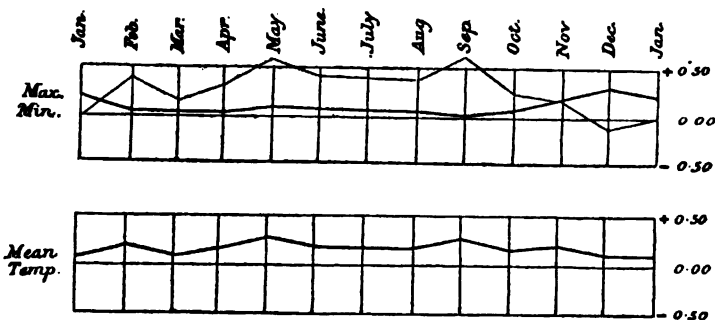


FIG. 2.

It thus appears that the differences between the Second Order system means and the civil day means are of the same general character as in the comparison given in the paper between the Climatological means and the civil day means, but are less in amount. There is not, however, such marked variation between the means of the minimum readings in different parts of the year as is shown in the comparison with the Climatological means.

The mean monthly numbers of Tables I., II., III., and IV., are graphically exhibited in the accompanying diagrams (Figs. 1 and 2).

DISCUSSION.

The PRESIDENT (Mr. Latham) asked if the same instruments were used for all the observations.

Mr. BAYARD said that he was much interested in these comparisons. He had thought, when the question of the difference between the Climatological and Second Order observations had occurred to him, that it would be very slight, and certainly Mr. Ellis's results showed that the variation was not greater than might be due to what was termed 'personal equation.' Very few observers would agree precisely when reading the same thermometer to tenths of a degree.

Mr. C. HARDING inquired whether Mr. Ellis could give any idea of the number of occurrences of abnormal variations between the climatological and civil day maximum and minimum temperatures. He was surprised that the difference between the means was not greater, for he had found when using the Greenwich climatological temperatures, that they frequently differed considerably from the civil day values.

Mr. MARRIOTT said that he was very pleased indeed that Mr. Ellis had taken up this subject, because it bore so closely on the system of observations organised by the Society. The table of differences between the Second Order and Climatological temperatures was very striking, and he was glad to see that there was such close agreement. He then proceeded to explain on the blackboard the principles upon which the Climatological and Second Order Observations were made, and showed how abnormal variations in temperature produced the differences between the maxima and minima observed under the conditions of the two methods.

Mr. SYMONS said that as it was only the civil day readings that differed so largely from the climatological readings, the results of this paper seemed to point to the desirability of the Greenwich Observatory authorities adopting the ordinary meteorological day, either ending at 9 a.m. or 9 p.m.

Dr. TRIPE said that there was every reason to be satisfied with the results of this comparison. The system of Climatological stations organised by the Society was chiefly arranged to suit the convenience of a large number of observers who found it impracticable to take regular evening observations, and the close agreement between the results of observations made by the same instruments on this plan and of those made under Second Order conditions, proved the wisdom of the course taken in establishing these Climatological stations on their present basis. He should have expected more *plus* signs during February than were shown in Mr. Ellis's tables, as a rise in the temperature during the night is a rather common occurrence in this month.

Mr. ELLIS in reply said that the maximum and minimum thermometers on the revolving stand, in the Stevenson screen, and on the roof of the Magnet House, are really different instruments, but it would be seen that it was not the indications of these different instruments that come into comparison in the paper, the results given being simply differences of the means of readings of the maximum and minimum thermometers on the revolving stand, as depending on the method of tabulation: they were therefore strictly comparable. The differences are not in general large, but they are real, and not of the character of personal equation. As regards the number of times that the daily maximum and minimum readings, taken according to the climatological plan, differ from the readings on the civil day system, the numbers for the year 1886 have been counted, with the following result:—

Month.		Maximum differs on	Minimum differs on	Month.		Maximum differs on	Minimum differs on
January	...	8 days.	18 days.	July	...	8 days.	7 days.
February	...	4 "	7 "	August	...	1 "	8 "
March	...	1 "	11 "	September	...	1 "	16 "
April	...	5 "	10 "	October	...	8 "	10 "
May	...	3 "	8 "	November	...	6 "	18 "
June	...	3 "	10 "	December	...	11 "	20 "

Monthly mean temperatures (mean of maximum and minimum) on the climatological plan may be considered to be practically similar to means on the Second Order system. But both differ from the civil day means. Since, how-

ever, it has been authoritatively laid down that, at primary stations, maximum and minimum readings should be tabulated according to the civil day, ending with midnight, we cannot, as suggested, give up the civil day arrangement, although if thought desirable the monthly means of readings might be given in addition, according to the Second Order system and Climatological plan.

On the distribution of Barometric Pressure at the average level of the Hill Stations in India, and its probable effect on the Rainfall of the Cold Weather.

By W. L. DALLAS, of the Meteorological Office, Calcutta.

(Communicated by R. H. SCOTT, F.R.S.)

(Abstract.)

[Received May 6th.—Read June 18th, 1890.]

THE author shows, by a comparison of the cold weather rainfall of India in January 1889 and January 1890, that whereas the former was in excess of the average over the greater part of North-western India and in Ceylon, the latter was very deficient in both quarters. On comparing the mean distribution of pressure in the two months as shown by stations on the plains, he finds that their main features are very similar, except that the general pressure was lower in the latter and drier year. In both years it was such as to produce a preponderance of anticyclonic winds. When, however, he compares the pressures at the hill stations (at elevations varying between 8,500 and 7,500 ft.) he finds that these afford evidence of baric gradients of very different intensities in the two years, and reversed in direction from those on the plains. According to the method of reduction adopted by the author, the gradients in January 1889 appear to be about double those prevailing in January 1890, and to this circumstance he attributes the greater prevalence of Southerly winds and rainfall in January 1889.

He also compares the barometric conditions, winds and rainfall of two storms that passed across Northern India in February 1889 and February 1890, and finds that at low levels their barometric features were remarkably alike, the rainfall being much heavier at the hill stations, while none fell in the Southern Punjab in the storm of the latter year, whereas in that of the former year it was more general on the plains. But in the barometric readings of the hill stations, he finds evidence of a very different distribution of pressure, and he considers that herein lay the explanation of the differences in the rainfall.

ON THE RELATIVE PREVALENCE OF DIFFERENT WINDS AT THE ROYAL OBSERVATORY, GREENWICH, 1841-1889.

By WILLIAM ELLIS, F.R.A.S., of the Royal Observatory.

[Received April 29th.—Read June 18th, 1890.]

Mr. Prince, of Crowborough Observatory, Sussex, having in his Meteorological Report for the year 1889 drawn attention to the greater prevalence of North-east winds which he has found to exist at Crowborough in recent years, I have thought that it would be interesting to put together the results derived from the records of the self-registering Osler anemometer of the Royal Observatory, Greenwich. The numbers contained in the annexed table are either copied or derived from those given in the annual volumes of *Greenwich Observations*. The results from 1841 to 1860 are given in an Appendix to the volume for 1860, and for the remaining years in the several annual volumes. Until 1869 the results are given for days, and since 1870 for hours. The day unit is, however, here retained for better comparison with Mr. Prince's values, or with those of other observers, that is to say the values for hours since 1870 have been divided by 24.

In considering this Table it would appear that in some of the earlier years the number of calm days is in excess of the true amount, arising probably from some rule having been adopted for the classification of days as calm which admitted too many, otherwise the same general balance of winds seems to be maintained throughout, the several means for 24 years and 25 years giving no indication of any great change in this respect, neither is there any appearance of change in late years such as Mr. Prince finds at Crowborough.

But to consider now the statements of Mr. Prince. He says, "The great preponderance of North-east wind over all other wind currents, and more particularly over that from the South-west, which has obtained during the last five years, has induced me to look through my journal since 1858 in order to ascertain whether I had a record of any similar condition of the principal wind currents of the South-east of England. For the thirty-one years, ending with 1889, I find only two instances in which the North-east has been in excess, viz. in the years 1864 and 1870."

The corresponding number of days of North-east and South-west winds for Crowborough and Greenwich in the years 1864 and 1870 are as follows:—

Year.	Crowborough.		Greenwich.	
	NE.	SW.	NE.	SW.
1864 ...	104	89	48	108
1870 ...	107	88	65	96

NUMBER OF DAYS OF PREVALENCE OF DIFFERENT WINDS IN EACH YEAR 1841 to 1889, AS DERIVED FROM THE RECORDS OF THE SELF-REGISTERING OBSER ANEMOMETER OF THE ROYAL OBSERVATORY, GREENWICH.

Year.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
1841	40	19	22	9	49	112	60	17	37
1842	46	40	31	15	31	112	38	25	27
1843	42	44	22	8	18	102	37	29	63
1844	48	57	18	14	22	89	35	26	57
1845	30	49	11	13	43	104	43	38	34
1846	27	25	21	18	39	94	32	23	86
1847	41	23	16	4	55	111	36	10	69
1848	53	38	19	36	58	90	29	20	23
1849	59	54	20	23	39	102	35	22	11
1850	49	48	24	21	30	116	27	19	31
1851	52	39	21	20	28	100	37	25	43
1852	45	58	36	21	52	108	27	8	11
1853	43	65	16	27	28	86	32	27	41
1854	31	45	17	20	30	117	42	30	33
1855	56	74	23	17	25	84	30	26	30
1856	44	54	27	30	31	80	50	26	24
1857	21	58	28	27	33	119	34	21	24
1858	26	61	38	27	26	106	40	29	12
1859	31	54	16	29	25	128	40	31	11
1860	30	47	26	19	22	120	64	31	7
1861	26	43	29	17	22	119	59	25	25
1862	27	46	20	32	17	118	71	22	12
1863	21	33	20	24	22	138	60	28	19
1864	44	43	34	27	28	108	32	16	34
1865	40	30	18	28	24	97	47	22	59
1866	28	31	27	14	28	119	62	22	34
1867	43	40	29	21	37	119	41	26	9
1868	39	43	20	19	37	113	54	18	23
1869	38	51	24	26	27	112	50	27	10
1870	39	65	29	24	26	96	49	28	9
1871	37	50	38	31	36	100	47	17	9
1872	35	23	17	24	50	123	61	17	16
1873	30	46	29	19	27	108	69	20	17
1874	37	36	29	23	30	104	80	21	5
1875	42	54	38	26	39	100	51	14	1
1876	45	40	40	35	41	94	55	16	0
1877	36	30	25	18	46	113	69	25	3
1878	48	36	37	20	32	94	63	28	7
1879	39	50	41	21	43	105	39	16	11
1880	38	65	34	16	37	106	42	15	13
1881	39	49	34	25	41	107	38	22	10
1882	26	35	25	28	46	127	41	22	15
1883	41	37	26	30	41	115	40	27	8
1884	40	42	38	25	41	103	49	18	10
1885	44	55	35	30	39	107	30	20	5

Again, on the average of 25 years, 1859 to 1883, Mr. Prince finds for Crowthorough, North-east 68 days, South-west 99 days. The corresponding Greenwich values are 48 and 111.

NUMBER OF DAYS OF PREVALENCE OF DIFFERENT WINDS IN EACH YEAR 1841 TO 1889, AS DERIVED FROM THE RECORDS OF THE SELF-REGISTERING SIGLER ANEMOMETER OF THE ROYAL OBSERVATORY, GREENWICH.—Continued.

Year.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
1886	42	49	44	20	40	97	45	16	12
1887	58	62	34	17	30	94	40	21	9
1888	49	49	33	24	39	105	41	18	8
1889	51	44	28	24	40	96	45	20	17
Means 1841- 1864.	39	46	23	21	32	107	41	24	32
Means 1865- 1889.	40	44	31	23	37	106	50	21	13
Means 1841- 1889.	40	45	27	22	35	106	46	22	22

Mr. Prince gives the average frequency of different winds 1885 to 1889. From the accompanying Table I have prepared corresponding numbers for Greenwich. We thus have:—

Mean prevalence of different winds, 1885 to 1889.

AT CROWBOROUGH.

N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
41	102	21	22	88	72	50	17	...

AT GREENWICH.

N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
49	52	35	28	87	100	40	19	10

Mr. Prince further gives averages of 47 years, which he has since informed me are for the years 1843 to 1889, as follows:—

N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
88	63	29	27	28	91	59	85	...

The Greenwich values for the corresponding 47 years from the annexed Table, are:—

N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
89	46	27	28	84	106	46	22	22

For the individual years, 1885 to 1889, the comparison as regards North-east and South-west winds is as follows:—

Year.	Crowborough.		Greenwich.	
	NE.	SW.	NE.	SW.
1885	...	98	55	107
1886	...	102	49	97
1887	...	128	62	94
1888	...	95	49	105
1889	...	88	44	96
Means	...	102	52	100

Thus the results for the two places are entirely at variance in late years in a way that has not previously been experienced in such persistent fashion. It would be now interesting to make comparison, if possible, with similar statistics derived from observations made at some southern station nearer to Crowborough.

DISCUSSION.

The **PRESIDENT** (Mr. Latham) said that he always preferred to ascertain the direction of the wind from the motion of low clouds or smoke. He did not trust to vanes, as they so frequently got fixed; and probably some of the differences shown in the paper might be due to errors in the vanes.

Mr. **SYMONS** read the following letter from Mr. Prince, of Crowborough Beacon:—

“Dear Mr. Symons,—As I find that I shall not be able to attend the Meeting of the Royal Meteorological Society on the 16th instant, I send you records as to the prevalence of North-east and South-west winds at Forest Lodge, Maresfield, and Crowborough respectively, the former from data kindly supplied to me by Capt. Noble, F.R.A.S.

“The vane at Forest Lodge is about 280 feet and mine 850 feet above sea-level. The observations were made at both stations at 9 a.m. Forest Lodge is situated nearly five miles in a south-west direction from Crowborough.

Years.	Crowborough.		Forest Lodge.			Greenwich.	
	NE.	SW.	NE.	SW.	Blank Days.	NE.	SW.
1885	98	74	77	71	51	55	107
1886	102	83	88	80	23	49	97
1887	128	67	120	71	33	62	94
1888	95	71	73	89	72	49	105
1889	88	65	96	78	37	44	96
Mean	102	72	90	75	43	52	100

“It will be seen by examination of the above table that the records kept at Forest Lodge are not complete, through absence of the observer, but by inserting corrections to the particular blank days taken from my own Journal at Crowborough we arrive at results given in the following table;—

	Crowborough.		Forest Lodge.		Greenwich.	
	NE.	SW.	NE.	SW.	NE.	SW.
Mean as above.....	102	72	90	75	52	100
The Mean + correction applied for 216 blank days at Forest Lodge.....	...	...	18	6	...	...
	102	72	108	81	52	100

“The application of this correction shows that the net reduced results at both places are practically the same.—Yours faithfully, C. LEESON PRINCE.”

Mr. **SYMONS** said that he did not think that Mr. Prince's vane was open to the charge of being fixed or stuck. He then described the position of the vane and the method by which its indications were read, and showed how he had thought that it was possible the vane may have become affected by a lofty addition to Mr. Prince's house. It did not, however, appear that such was the case, as the observations made by Capt. Noble at Maresfield, about five miles distant from Crowborough, confirmed Mr. Prince's results. A vane fixed to a pole or mast often gave very unreliable observations. He had had a vane so fixed in his own garden, and had found that in dry weather the pole cracked and gradually

twisted round until the cardinal points had moved as much as 40° from their true position. When damp weather set in the pole twisted back to its proper position.

Mr. C. HARDING said that he had compared the wind observations obtained by the Meteorological Office for 8 a.m. each day at London, Dungeness and Hurst Castle for the five years 1885 to 1889, and had found the number of days of North-east and South-west winds to be as follows:—

Years.	London.		Dungeness.		Hurst Castle.	
	NE.	SW.	NE.	SW.	NE.	SW.
1885	42	69	38	56	72	63
1886	41	62	41	46	78	67
1887	58	53	65	45	92	51
1888	51	65	41	65	72	75
1889	48	60	40	56	73	56
Mean for 5 years	48	62	45	54	77	52

Considering the mean result for the five years 1885-9, and taking the North-east winds as unity, the respective results are—

					NE.	SW.
Crowborough	...	...	...	...	1	0·7
Greenwich ...	...	...	...	...	1	1·2
London ...	...	...	...	...	1	1·8
Dungeness	...	...	...	...	1	1·2
Hurst Castle	...	...	...	...	1	0·7

He could not say whether the last few years had been exceptional with respect to the prevalence of North-east winds, but it was noteworthy that recent years have been marked by an absence of great storms so far as the British Islands are concerned, and more especially over the South of England.

Mr. ELLIS said, regarding the question of periodical variations of the wind, that he did not himself attach much importance to such periodicities as were pointed out by Mr. McDowall (see next paper), considering them to be more of accidental character, rather than as indicating recurring phenomena. On the question of the sticking of vanes he might, perhaps, mention an experiment which he once made with the Greenwich Osler vane, as showing the delicacy of its action. It may be premised that a collar on the vane shaft bears upon anti-friction rollers, running in a cup of oil, rendering the vane very sensitive to changes of direction in light winds. On the occasion in question the Robinson cups were turning at the rate of about four revolutions per minute, indicating a very low velocity. The Osler vane was pointing South-by-west. It was turned by hand to East, but, when released, slowly came back to South-by-west. It was then turned to West, and similarly came back nearly to South-by-west. Other trials have been made with similar results.

ON SOME RECENT VARIATIONS OF WIND AT GREENWICH.

By ALEX. B. MACDOWALL.

[Received April 29th—Read June 18th, 1890.]

Among the tabular statements issued from the Royal Observatory, Greenwich, is one which shows the relative proportion of wind each year reduced to the four cardinal directions. These four numerical series present some interesting features of variation,—the nature of which appears to call for more elucidation than it has yet received.

In the accompanying diagram are given (lower part) two curves showing the variations in Easterly and Southerly wind during the last 30 years (1860-89). The horizontal dotted line indicates the average of Easterly wind during the period (69·9 days).

In studying these and the other data, we are led to note the following points :—

(1.) The proportion of Easterly winds has been in general increasing. Observe the general rise in the curve and its successive maxima ; traversing at times within the last ten years the curve of Southerly winds.

In the first 15 years, the sum of the days is 962 ; in the second it is 1135. Grouping the years in fives, we have the following sums :—

817, 901, 844, 864, 867, 404.

(2.) The fluctuations in the proportion of Easterly winds tend to widen. Thus, if we compare the intervals between minima and their following maxima, we have the series :—

22, 29, 30, 41, 49.

(3.) The recurrence both of minima and maxima presents a certain regularity. We find minima in 1863, 1867, 1872, 1877, 1882, and 1888, giving the series of intervals

4, 5, 5, 5, 6 years.

Relative maxima are found in 1861, 1864, 1871, 1875, 1880, and 1885 ; giving the series of intervals

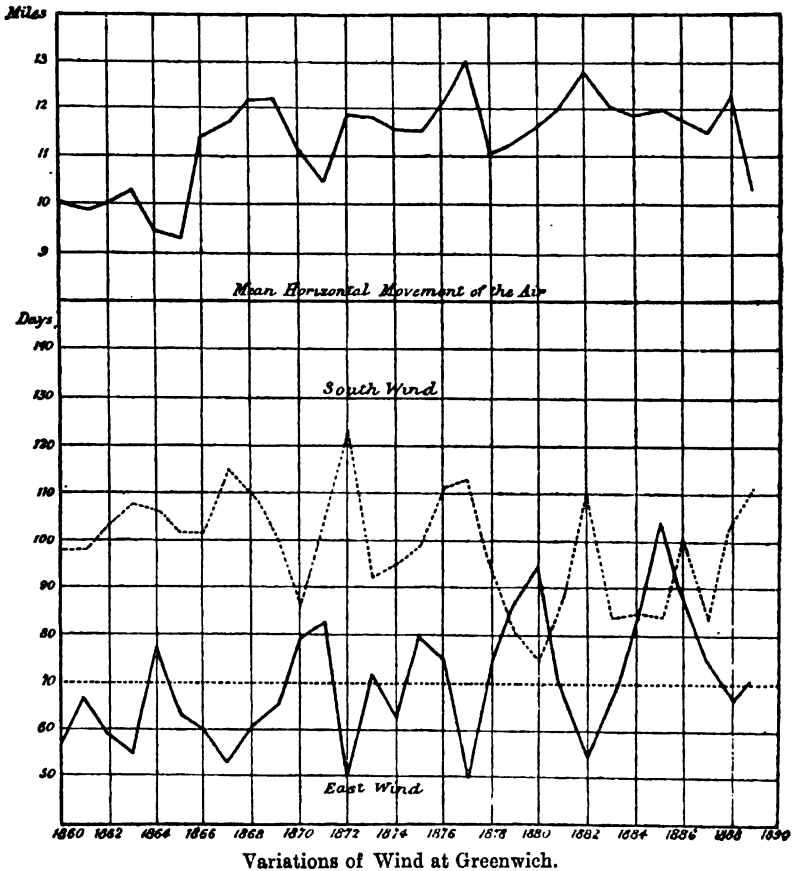
8, 7, 4, 5, 5 years,

which is evidently less regular.

(4.) To the minima of Easterly wind generally correspond maxima of Southerly wind, and to some extent maxima of Easterly wind are found with minima of Southerly wind. Thus the curve of Southerly wind presents more or less regular recurrences ; the intervals between the maxima are 4, 5, 5, 5, &c. The series of minima is rather irregular.

The most noteworthy features of the two remaining curves, for Northerly and Westerly winds respectively (which seem very irregular, and are not here given), are perhaps these :—

(5.) There is a general rapid rise in the proportion of Northerly wind from an absolute minimum in 1882 to an absolute maximum in 1887; and there is a continuous fall in the curve of Westerly winds from an absolute maximum in 1888 to the lowest point yet reached (in those 30 years), in 1889.



The numbers are as follows :—

	1882.	1883.	1884.	1885.	1886.	1887.	1888.	1889.
North.	48	60	76	64	67	100	90	93
West.		154	123	114	110	108	106	90

The maxima of Southerly wind correspond sometimes with a high point, sometimes with a low one, in either of the curves of Northerly and Westerly wind.

Comparing a curve of mean horizontal movement of the air at Greenwich (see diagram, upper part) we find that

(6.) The minima of Easterly winds and maxima of Southerly winds generally correspond with relative maxima in the curve of horizontal movement. (It is known that Easterly winds have the least average intensity of all winds; being weaker than Northerly, these again than Southerly, and these than Westerly.) We have then in this horizontal movement curve another case of recurrence, finding relative maxima at the following intervals :—

5, 4, 5, 5, 6 years.

(7.) There is apparently a similar recurrence in severe winters (in recent years). Comparing the winters of those 80 years in respect of severity, we find relative maxima (of severity) in the following years: 1864-65, 1869-70 (interval 5 years), 1874-75 (5 years), 1879-80 (5 years), 1885-86 (6 years). These winters correspond pretty nearly, it will be seen, with the maxima of Easterly wind.

A proximate explanation of this recurrence of about 5 years would, no doubt, appear from a comprehensive survey of the conditions of barometric pressure obtaining throughout those 80 years. But the causes of relative displacement of those barometric maxima and minima, from time to time (producing wind variations), are still in the main a *terra incognita* for meteorology.

Do these data, it may be asked, afford any ground for prediction? One can only say, that should this recurrence (say) in the curve of Easterly wind be continued, we should rather expect, having passed a minimum, apparently in 1888, to have, during this year (1890) and next, increasing proportions of Easterly wind. On the other hand, the high position now reached by the curve for Northerly winds, and the very low position of that for Westerly winds, would lead us to expect an early fall in the former and rise in the latter. And a study of winters with regard to relative severity, appears to suggest, that next winter will be still milder than its mild predecessor. But knowing how certain the unexpected is in meteorology, I shall not venture further on dangerous ground.

ON THE ACTION of LIGHTNING DURING THE THUNDERSTORMS of JUNE 6th & 7th, 1889, AT CRANLEIGH, SURREY.

By CAPT. J. P. MACLEAR, R.N., F.R.Met.Soc., F.R.G.S.

[Received June 7th—Read June 18th, 1890.]

DURING the thunderstorms of June 6th and 7th, 1889, so many trees were struck within a radius of 4 miles from Cranleigh, that I set to work to discover, if possible, the cause of selection of these particular trees; for, contrary to general expectation, they were not the highest nor the most prominent in their immediate vicinity; and though I cannot say I have solved the question, as the causes of preference appear to be very slight, yet I think I can put forward some interesting facts which may help us to a further knowledge of the nature of the electric discharge, and the course it may be likely to follow.

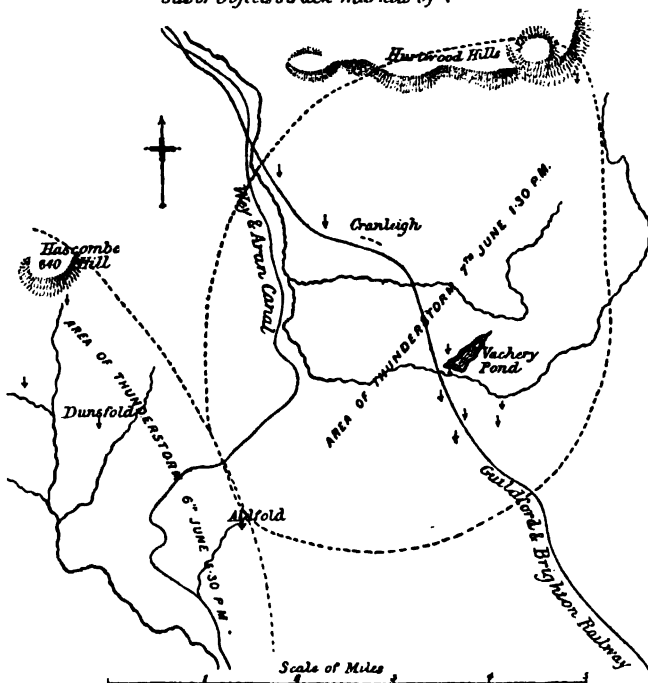
On June 6th, the storm first appeared to the southward of Cranleigh, about 4.48 p.m., and it passed about 4 miles to the South-west. About 5.30 p.m., shortly before rain commenced, the following objects were struck, apparently about the same time, but, as no accurate observations were made as to time, it cannot be determined whether one or several discharges were concerned. On Dunsfold Common, 4 miles South-west of Cranleigh, a cottage was struck, a chimney at the south-east end knocked down, and the register grates on two floors started from their places; a haystack about 100 yards south of the cottage was set on fire, and two poplars 800 yards west of the cottage were struck, each tree having a score down it, $1\frac{1}{2}$ inches width of bark being stripped off. On Hascombe Hill, $1\frac{1}{2}$ miles north of the cottage, and 400 feet above its level, a spruce fir was shivered; at Alfold, $1\frac{1}{2}$ miles south-east of the cottage, two oaks were struck, one was only scored but the other was split (this latter tree was struck again and splintered the next day); also three oaks about a mile to the westward of the cottage were struck, but as it is only conjecture that they were struck at the same time I shall not refer to them again. More trees may have been struck in the neighbourhood but not noticed.

As for the causes of these objects being selected, it will be seen that they lie nearly in a line North-west and South-east 8 miles in length. Mr. Marriott has shown (*Quarterly Journal*, No. XV. p. 222) that the storm was passing in a north-west direction with a South-east wind; it is possible that the storm was delayed by the high Hascombe hills and the charged cloud thereby concentrated. The spruce fir was very prominent on the southern brow of the hill; it divided into two arms nearly in line with the stem; one arm

was thrown to the ground, the other blown down by the wind a few hours afterwards. At the junction of the arms there was a great deal of turpentine, which was thoroughly blackened. In this case I should consider that the prominence of the tree made it the best communication to earth, and that the collection of turpentine at the juncture of the arms was raised to explosive temperature and split the tree.

The cottage, haystack and two poplars on Dunsfold Common do not immediately suggest a cause of selection, but from their position the ground falls to the south-east in a wooded valley through which the Arun and Wey canal runs, and on the other side of this wooded valley are the Alfold trees. Streams into the canal run from near all the objects struck, and though I hesitate to advance this point, it is possible that the earth electricity was thus able to collect more readily at these places than at others under the cloud. It would be exceedingly interesting to know if these three objects were all struck by the same discharge.

SKETCH OF THUNDERSTORM AREA OF JUNE 6th & 7th 1889.
Site of Objects struck marked by †



On June 7th, the storm began with little warning at 1.10 p.m., and was at its height at 1.27, when there fell the heaviest rain known to the oldest inhabitant. About 1.30 p.m. the following objects were struck:—Near Vachery pond, a large reservoir for the Arun and Wey canal $1\frac{1}{4}$ mile south-east of Cranleigh, six oaks, a chestnut, and an ash, in various positions within

$\frac{1}{2}$ mile of the pond and about $\frac{1}{2}$ of a mile apart, a young fir and three young oaks in the middle of a copse on the slope of the ground near the pond, four oaks $\frac{1}{2}$ a mile south of Cranleigh, one oak on Cranleigh Common, a chimney and stable 1 mile north-west of Cranleigh, besides the oak tree before mentioned at Alfold, and a single oak occupying a fairly prominent position on the slope of the high hills $2\frac{1}{2}$ miles to the north-east of Cranleigh. This last tree was struck just before the rain commenced on the hill, and was split; the other trees struck, during the rain, were only scored.

Here the area of discharge extends along a line about three miles in length North-west and South-east, as on the previous day; and with the exception of the Alfold tree before referred to 8 miles to the south-west, and the tree on the hill 8 miles north-east, all the objects struck were scattered along the line of railway, and at no great distance from it.

It is not easy to see the cause of selection, for these trees were not the most prominent nor were they on the highest ground in the vicinity; the only feature the groups possessed in common being that they were all either near ditches which were full of running water, or else near temporary courses taken by the deluge of water from the higher to the lower ground. The most puzzling case is that of the young fir tree and three young oaks in the middle of the copse near Vachery pond; they were not higher than the other trees in the copse, but there certainly was a temporary water course running close to them; other trees, however, stood equally close to the water, and unless a large squirrel's nest of moss on the top of the young fir be called upon to account for the selection, it still remains obscure. Another curious case is that of the stable struck, which was overshadowed by tall elms, where it might have been supposed that these would have taken the stroke.

Of the species of trees struck, the oak is the most frequent, and I am inclined to believe that the reason is not that there are more oaks than other trees in the neighbourhood, but that the roughness of the bark causes gaps of its continuity as a conductor; elms, firs, poplars and chestnuts have been struck, but it is said that the beech is never struck.¹ It has been said, also, that oaks are more frequently struck in the spring and other trees in the autumn, but this requires confirmation.

The injuries to the trees are of two kinds: the first, by far the most common, is simply a score out of the bark up the trunk of the tree, out along one limb, and then by perhaps two or three branches to the outer twigs; in some cases portions of the bark are blown off as well. A very good illustration of this effect is found in a paper by the Rev. O. P. Cambridge, *On the effect of a flash of lightning at Bloxworth, April 9th, 1886.*² In these cases I imagine that the rain is falling, and one or more streams of water are running down the sides of the tree, forming a conductor which becomes insufficient, at the time of discharge, to carry off all the electricity, and

¹ *The Action of Lightning.* By Col. Parnell, p. 27.

² This paper is in the Library of the Royal Meteorological Society.

therefore becomes so suddenly converted into steam as to blow out the bark along the line, and if there is communication with the sap by a knot, hole, or other flaw, the sap is also converted into steam and the bark blown off.

The other form is the shattering of the tree, which I imagine to occur when the electricity is insufficiently carried off by the outer surface, and collects at the junction of some main branch with either the stem or with some other branch, where there is perhaps a cavity with water in it, or a collection of moist dead leaves; the tree is then easily rent by the explosion of steam generated. If the tension be very great, and especially if the air round the tree be dry, the sap may be violently exploded, and the trunk splintered and shattered as if by dynamite.

Of the trees which I have examined here, the only ones shattered were those struck before the rain fell; the others were scored simply, with bark blown off.

In the case of the stable struck on June 7th, I can only think that the electricity collecting at the top of the overhanging elm tree found a better conductor than the trunk in the hot moist air escaping from the near gable of the stable, and the hot air expanding blew the corner tile off to find a better vent. As to the cottage on Dunsfold Common struck on June 6th, I can trace no cause for selection; the appearance of the chimneys suggests an explosion of air.

As the result of my examinations I can only say that the causes of selection of objects struck appear too slight to be readily perceptible, or to enable one to say beforehand that such and such an object will probably be struck. It seems that during rain every tree is conducting electricity, and a disruptive discharge takes place where the conductor becomes insufficient. This would depend on the position of the cloud, the amount of foliage on the tree, its condition of moisture, and its connection with running water. Also I may point out, as shown by Prof. O. J. Lodge, that if an upper cloud should discharge to a lower one, the lower one may then discharge to earth violently without regard to any conductors.

It would be desirable if those who have the opportunity of observing objects immediately after they are struck would note the surrounding conditions and proximity to water, and whether, in the case of trees struck during rain, the score is on the side on which the rain beats.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

MAY 21ST, 1890.

Ordinary Meeting.

BALDWIN LATHAM, M.Inst.C.E., President, in the Chair.

WILLIAM FRIESE GREENE, 92 Piccadilly, W.; and
FRANCIS HOLMES PHILLIPS, 1 Prestonville Road, Brighton,
were balloted for and duly elected Fellows of the Society.

The following Papers were read:—

"RAINFALL OF THE GLOBE.—COMPARATIVE CHRONOLOGICAL ACCOUNT OF SOME
OF THE PRINCIPAL RECORDS." By W. B. TRIPP, M.Inst.C.E., F.R.Met.Soc.
(p. 198.)

"MUTUAL INFLUENCE OF TWO PRESSURE PLATES UPON EACH OTHER, AND
COMPARISON OF THE PRESSURES UPON SMALL AND LARGE PLATES." By W. H.
DINES, B.A., F.R.Met.Soc. (p. 205.)

"ON THE VARIATIONS OF PRESSURE CAUSED BY THE WIND BLOWING ACROSS
THE MOUTH OF A TUBE." By W. H. DINES, B.A., F.R.Met.Soc. (p. 208.)

JUNE 18TH, 1890.

Ordinary Meeting.

BALDWIN LATHAM, M.Inst.C.E., President, in the Chair.

CLINTON COLERIDGE FARR, B.Sc., St. Luke's Parsonage, Whitmore Square
Adelaide;

JOSEPH HALL, Assoc.M.Inst.C.E., Town Hall, Torquay;

CHARLES ROBERT RIVINGTON, 74 Elm Park Gardens, S.W.; and

JOHN LIVESAY WHITEHEAD, M.D., Belgrave House, Ventnor, Isle of Wight,
were balloted for and duly elected Fellows of the Society.

The following Papers were read:—

"ON THE DIFFERENCE PRODUCED IN THE MEAN TEMPERATURE DERIVED FROM
DAILY MAXIMUM AND MINIMUM READINGS, AS DEPENDING ON THE TIME AT WHICH
THE THERMOMETERS ARE READ." By WILLIAM ELLIS, F.R.A.S., F.R.Met.Soc.
(p. 218.)

"ON THE DISTRIBUTION OF BAROMETRIC PRESSURE AT THE AVERAGE LEVEL OF
THE HILL STATIONS IN INDIA, AND ITS PROBABLE EFFECT ON THE RAINFALL OF
THE COLD WEATHER." By W. L. DALLAS. (p. 220.)

"ON THE RELATIVE PREVALENCE OF DIFFERENT WINDS AT THE ROYAL
OBSERVATORY, GREENWICH, 1819-1889." By WILLIAM ELLIS, F.R.A.S.,
F.R.Met.Soc. (p. 221.)

"ON SOME RECENT VARIATIONS OF WIND AT GREENWICH." By A. B. Mac-
DOWALL. (p. 226.)

"ON THE ACTION OF LIGHTNING DURING THE THUNDERSTORMS OF JUNE 6TH
AND 7TH, 1889, AT CRANLEIGH, SURREY." By Capt. J. P. MACLEAR, R.N.,
F.R.G.S., F.R.Met.Soc. (p. 229.)

CORRESPONDENCE AND NOTES.

CONDITIONS OF TORNADO DEVELOPMENT.

LIEUT. J. P. FINLEY, U.S.A., in his Prize Essay on "Tornadoes,"¹ gives the following as the conditions under which Tornadoes are formed :—

Tornadoes form in connection with cyclonic areas of low pressure, to which they bear certain relations that can be defined.

Not all low pressure areas develop the conditions necessary for tornado formation, which are :—1st. Unstable equilibrium ; 2nd. A gyratory motion of the air relative to some centre of circulation. The second condition is always present, to a greater or less degree, in every cyclone, but the combination of the two, the *sine qua non* of tornadic development, fortunately, for some very good reasons, occurs with much less frequency.

There is good reason for the opinion that a certain form of the area of low pressure (trough-like, trending north and south, or north-east and south-west) is more conducive to tornado conditions than any other. Such a form of depression brings in closer proximity the opposing conditions of heat and moisture of the north-west and south-east quadrants of the low, which state of things is especially favourable to the development of unstable equilibrium (the most important factor in tornado generation) in the South-east quadrant.

It is now no longer a moot question that tornadoes form in a certain quadrant (the south-east) of the low area which they attend.

The reason for this is found in the fact that this quadrant is the great heat and moisture region of the low, and where the circulation of the warm moist air, underneath the cold, anticyclonic air currents from the North, gives rise to the development of unstable equilibrium.

Not only is the South-east quadrant the tornadic region of the low, but it is also the region which gives birth to all violent local storms. All such disturbances depend upon unstable equilibrium as an initiatory force.

The results of the study of tornado maps may be briefly summarised as follows :—

1. That the tornado region is not coincident with area of lowest pressure.
2. The tornado region is confined to the south-east quadrant of the low.
3. The tornado region is several hundred miles south-eastward from the general storm centre.
4. The south-east quadrant is the region of greatest heat and moisture in the low. As to moisture, the North-east quadrant is also prominent.
5. The south-east quadrant is the local storm region of the low.
6. The local storm region is within the belt of Southerly winds.
7. The line of separation between Northerly and Southerly winds approximately marks the limit of precipitation to the east and west.
8. The area of precipitation moves eastward with this line.
9. That along this line, on both sides of it, the heaviest precipitation generally occurs, and also some of the heaviest winds.
10. The average wind velocity is generally highest in the south-west and north-west quadrants, followed next in order by the south-east quadrant.
11. The highest wind velocities (25 miles per hour and upward) occur in the south-west quadrant, where they are also the most frequent.
12. The south-east quadrant stands next in order to the south-west for maximum wind velocities, both in number and degree.
13. The north-west quadrant stands third in order, followed by the north-east quadrant with no maximum velocities.
14. The maximum velocities are principally confined to the latter half of the day, especially in the south-east quadrant.
15. As the low approaches the meridian of the tornado region the Southerly winds gradually increase in velocity, the isotherms curve more to the north, the moisture increases and the dew-point rises.
16. In the morning the highest wind velocities in the south-east quadrant are near the centre of the low, and during the afternoon and evening, near the centre of the tornado region. [Continued on p. 286.]

¹ *American Meteorological Journal*. Vol. VII. p. 166.

RAINFALL IN CHINA IN 1889. By WILLIAM DOBSON, Ph.D., F.R.Met.Soc., Government Astronomer, Hongkong.

Station.	Lat. N.	Long. E. Greenwich.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	°	'	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Yuenan	39	9	167	83	257	08	250	579	751	708	265	274	109	..	3451
Honki	38	4	..	..	..	..	..	194	705	182	130	120	..	30	1361
Chefoo	37	34	..	05	47	32	15	199	114	481	315	166	172	..	2546
Chemulpo	37	29	126	37	92	49	69	191	1010	118	273	270	304	18	3003
Shantung Promontory	37	24	122	42	..	..	..	142	608	218	398	55	146	..	1838
Fusan	35	5	129	6	225	48	193	562	1674	686	222	62	120	114	5760
Chinkiang	32	12	119	30	58	178	79	272	221	372	492	721	100	..	4998
Shaweshan	31	25	122	15	104	267	407	1998	802	345	309	1007	174	24	4967
Wuhu	31	22	118	22	280	279	431	367	372	133	805	835	227	05	5205
North Saddle	30	52	122	40	167	266	260	184	339	265	1239	904	242	05	3284
Hankow	30	33	114	20	149	306	666	917	351	308	982	513	105	12	8202
Iohang	30	12	111	19	62	191	74	520	877	1493	982	513	105	12	5878
Sleep Island	30	12	122	36	169	344	440	282	98	216	339	667	192	12	3378
Ningpo	29	58	121	44	765	518	532	686	980	1865	643	1375	307	52	8579
Kinkiang	29	43	116	7	387	404	212	978	761	352	771	889	385	25	6581
Wenchow	28	0	120	35	259	399	384	1066	843	1296	152	676	197	155	7094
Foochow	26	8	119	38	168	231	686	541	187	597	61	620	582	120	4431
Middle Dog	25	58	120	2	722	191	596	560	410	48	122	550	177	78	2896
Tam Sui, Formosa	25	10	121	25	108	523	728	697	878	840	10	433	964	232	7274
Keelung, Formosa	25	8	121	45	2769	1373	1145	669	826	622	255	2529	1725	1166	14351
Ookeu	24	59	119	28	105	175	338	540	489	138	..	57	135	20	2514
Amoy	24	27	118	4	179	360	329	350	758	295	41	402	205	130	4246
Chapel Island	24	10	118	13	113	136	229	600	696	147	42	364	340	02	3218
Fisher Island	23	33	119	28	58	158	63	1208	1514	507	60	278	69	..	4393
Swatow	23	30	116	43	206	160	262	389	1631	891	223	260	237	08	6357
Lamocks	23	15	117	18	76	96	290	1767	1431	162	43	363	82	..	4715
Canton	23	7	113	17	67	98	337	699	1767	151	162	551	87	18	5892
Amping	22	59	120	13	69	28	297	705	1940	1302	174	71	..	..	8499
Breaker Point	22	56	116	28	94	177	353	2073	2074	150	541	573	46	03	6760
Takow	22	36	120	16	49	08	78	1175	1641	1350	170	452	19	03	6566
Hongkong	22	18	114	10	73	72	249	4884	971	1814	1180	872	154	17	11971
South Cape, Formosa	21	55	120	51	203	69	198	579	1325	2089	316	2796	389	145	9086
Pakhoi	21	29	109	6	110	56	310	334	319	3035	1248	110	285	22	6747
King Chow, Hainan	20	3	110	20	26	166	46	503	313	1342	644	806	482	53	5168

17. In the south-west quadrant the highest wind velocities are most distant from the centre of the low in the morning, thereafter gradually drawing nearer, reaching the nearest point in the evening.

18. In the North-west quadrant the conditions are similar to those in the south-west quadrant, except that the highest velocities are near the centre of the low.

19. The wind velocities in the north-east are not particularly strong.

20. The wind velocities here referred to appear to have important connection with the tornado region, especially those occurring in the south-west and south-east quadrants.

21. The apex of the curve of high temperature is much nearer the centre of the low than the apex of the curve of low temperature.

22. The tornado region does not coincide with the region of the highest temperature gradient, as shown by the surface observations, but lies to the south and east of it several hundred miles, being nearest about noon, and most distant about sundown.

23. There are two regions of marked temperature gradient, the most decided lying between the northern portion of the South-east quadrant and the southern portion of the north-west quadrant, the other region lying between the northern portion of the south-west quadrant and the southern portion of the south-east quadrant.

24. The tornado region (in the particular case under consideration) lies nearest the southern temperature gradient region.

25. In some cases the tornado region lies about half-way between the two temperature gradient regions, and sometimes nearer the northern one, yet more frequently nearest the southern region.

26. As practically the whole of the south-east quadrant of the low is subject to unstable equilibrium, it is rather difficult to say just where the most decided conditions will manifest themselves. In this connection it must be borne in mind that all violent local storms result from unstable equilibrium, and that the hailstorm is a tornado above the surface of the ground.

27. As the unstable equilibrium which gives rise to a tornado appears to first manifest its force in the cloud region, where the whirl always starts, it is not strange that the surface observations frequently fail to show a direct connection therewith.

The tornado is there, and, with the aid of both local and telegraphic stations properly distributed, the weather chart may be able to furnish the desired information for prognostication.

Observations at considerable heights, from captive balloons, may prove very useful in this connection.

THE CLIMATE OF MALTA.

In a paper on "The Maltese Islands, with special reference to their geological structure," in the *Scottish Geographical Magazine* for September 1890, Dr. J. Murray gives the following account of the climate:—"The mean January temperature in Malta is 54°·5; the mean temperature of the three winter months (December, January, February) is 56°·0; the rainfall for the same months is 17°·5 ins., and during this time there are frequently hailstorms, but no snow. The mean annual temperature is 67°·3, and the annual rainfall 24·23 ins. During the eight cool months the thermometer only on rare occasions falls below 50°, and does not rise above 71° or 72°. In summer the heat is almost tropical, the temperature ranging between 75° and 90°, and there is little or no rain. For three successive years—from 1467 to 1470—no rain is said to have fallen at Malta, and the islands suffered greatly from drought. In 1852 only 8·27 ins. fell, and in 1866 only 10·49 ins. are recorded.

"The Northerly wind is bracing, and sometimes approaches the force of a gale.¹ In February 1889 this wind was so cold that in driving it was necessary to wear heavy fur coats and jackets; and at times the wind was accompanied with such heavy falls of hail that the ground became quite white for an hour or

¹ "Gregale," or Euroklydon.—Acts xiv. 14.

two. The South-west wind—the Scirocco from the African deserts—is very enervating; though this is a dry wind in Africa, it is in Malta charged with vapour, and while it is blowing, the pavements of the streets are wet, and everything feels damp. There are no rivers nor marshes on the islands, but during heavy rains the valleys are filled with torrents. Springs are found at the junction of the upper limestone with the underlying beds of clay and marl. The rain is speedily absorbed by the porous rocks. Earthquakes are relatively frequent, and coincident with disturbances in the Eastern Archipelago."

RECENT PUBLICATIONS.

AMERICAN METEOROLOGICAL JOURNAL.—A Monthly Review of Meteorology and Medical Climatology. July-September 1890. Vol. VII. Nos. 8-5. 8vo.

The principal original articles are :—Professor Elias Loomis; by Prof. H. A. Newton (20 pp. and portrait). This is a memorial address reprinted from the *American Journal of Science and Arts*.—State Tornado Charts; by Lieut. J. P. Finley (21 pp.). The States here dealt with are Florida, South Carolina, Minnesota, Mississippi, Kentucky, and Tennessee.—Trombes and Tornadoes; by H. Faye (21 pp.). This is a continuation of articles from the previous Nos. —Prize Essays on Tornadoes (65 pp.). The Editors and Publishers of the *American Meteorological Journal* some time ago offered prizes for the best essays on Tornadoes; and the August No. contains the prize essays in full. The first prize was awarded to Lieut. J. P. Finley, and the second to A. McAdie. There were two essays judged worthy of mention, between the authors of which the third prize has been equally divided, viz. Prof. H. A. Hazen, and J. M. Bennett. —A new recording rain and snow gauge; by S. P. Fergusson (2 pp.).—Espy's experiments on storm generation; by Prof. H. A. Hazen (4 pp.).—Origin of Storms; by E. B. Garriott (4 pp.).—Forests and Soil Temperatures; by M. W. Harrington (18 pp.).

BRITISH RAINFALL, 1889.—On the Distribution of Rain over the British Isles during the year 1889, as observed at nearly 8,000 stations in Great Britain and Ireland, with Articles upon various branches of Rainfall work. Compiled by G. J. SYMONS, F.R.S. 1890. 8vo. 288 pp. and 5 plates.

This contains the particulars of the rainfall from 2,708 records. The rainfall for the year 1889 was about 8 per cent less than the average. In addition to the Observers' notes and other usual information, there is a long article (26 pp.) on the Amount of Evaporation. Mr. Symons gives an account of the experimental observations which were carried out at Strathfield Turgiss some years ago, and also describes the various evaporators used. The little tin vessels called evaporators were soon found to be utterly worthless, being so much affected by temperature. A galvanised iron tank, 6 feet square and 2 feet deep, and sunk in the ground so that the rim was 8 ins. above the grass, was found to give the best results, and regular observations have been made from this tank at Strathfield Turgiss from 1870 to 1888, and since then at Camden Square. The mean annual evaporation was: Strathfield Turgiss 1870-83 (14 years) 18·08 ins.; and Camden Square 1885-89 (5 years) 14·54 ins.

CYCLONE MEMOIRS. PART II. BAY OF BENGAL CYCLONE OF AUGUST 21ST-28TH, 1888. Published by the Meteorological Department of the Government of India under the direction of J. ELIOT, M.A., Meteorological Reporter to the Government of India, 1890. 8vo. 183 pp. and 18 plates.

This paper has been written by Mr. A. Pedler, Meteorological Reporter to the Government of Bengal. The storm was undoubtedly one of the class which usually forms during the rainy season in the Bay of Bengal, and not of the class

of the fierce cyclones which are generated at, what are called, the transitional periods, i.e. from April to the end of May, and from the middle of September to the beginning of November. But though it was of the feeble class of storms, called the cyclonic storms of the rains, the storm in question was in one quadrant at least of force almost equalling that which is usually experienced in the most destructive cyclones, and was of sufficient force to almost cause the loss of one, if not of two vessels. The storm was generated close to the land at the head of the Bay of Bengal, within a few miles of Saugor Island. This area has in its neighbourhood several meteorological observatories, and thus affords an excellent opportunity of watching the meteorological conditions which precede and accompany the formation of such a storm. The northern half of the storm after its formation was well over the land, and was of feeble character, as was also at first all the area near the centre of the storm, but in the southern half, which lay over the sea at a considerable distance from land, the cyclonic winds were extremely violent, and an attempt is made to account for the more remarkable distances in the wind-force in different parts of the storm which are here indicated. It is shown that at first the fierce part of the storm was confined to an area from about 90 to 200 miles to the south of the centre, but that as the storm passed inland the area of strong winds gradually closed up and came nearer and nearer to the centre. Another point of importance in the storm was the fact that the centre of the barometric depression was many miles to the south of the centre of the circulation of winds, which fact is perhaps connected with the distribution of the strength of the winds in the storm. The storm was also remarkable for the slight barometric depression which accompanied it when the excessive force of the winds is considered, and was very noticeable for the particularly heavy wave of rainfall which was brought up in its rear. Finally, there was another interesting feature in the storm, inasmuch as it was formed while there was a second, but smaller, storm already in existence, which had been for some days travelling across India in a westerly direction.

HAND-BOOK OF CYCLONIC STORMS IN THE BAY OF BENGAL. For the use of Sailors. By JOHN ELIOT, M.A., Meteorological Reporter to the Government of India. 1890. 8vo. 212 pp. and 29 plates.

The object of this volume is to give the mariner who navigates the Bay of Bengal an account of the dangerous storms that occur in it, to state and explain the signs and indications by which he may ascertain when he is approaching a cyclone, or that a cyclone is forming in that part of the Bay which he is traversing, and to furnish him with information and methods by which he may ascertain sufficiently for all practical purposes the bearing or direction of the storm-centre, and of the path of any cyclonic storm he may meet with in the Bay. The subject is treated under the following heads:—(1). Explanation of meteorological ideas and phrases and of some of the more important principles of the science; (2). Description of the chief phenomena of cyclonic storms in the Bay of Bengal, and explanation of methods of ascertaining the existence, position and course of cyclonic storms; (3). Brief account of six of the most important and typical storms in the Bay of Bengal during the past 25 years; and (4). Summary giving brief practical hints respecting storms for the use of sailors navigating the Bay of Bengal.

JOURNAL OF THE ASIATIC SOCIETY OF BENGAL. Vol. LIX., Part II., No. 1, 1890. 8vo.

Contains a paper by Mr. J. Eliot, entitled "On the occasional inversion of the temperature relations between the hills and plains of Northern India" (50 pp.). The paper really consists of three parts:—(1). A statement of the normal meteorological temperature conditions of the plain and hill districts of Upper India in the month of January, and of certain meteorological conditions and actions upon which temperature mainly depends; (2). A statement of the more striking abnormal relations of the month of January 1889 and of the cold weather period generally in Upper India; and (3). A discussion of the causes which produce these unusual conditions and temperature variations. The author shows that inversion may occur over very large plain areas, and that it has, in some cases at least, little or nothing whatever to do with air motion between hills and valleys. He

also shows that the vertical temperature relations during the cold weather in Northern India are much more variable and complicated than they have been hitherto supposed to be, and that the descensional motion which accompanies cooling of the air during the night in fine clear weather is almost entirely one of slow compression, and is not the opposite of the ascensional and convective movement which takes place largely during the day.

METEOROLOGICAL OBSERVATIONS MADE AT SANCHEZ (SAMANÁ BAY), ST. DOMINGO, 1886-1888. By the late W. REID, M.D. Published by the Authority of the Meteorological Council. Official No. 89. 1890. 4to. 64 pp.

Samaná Bay is a large inlet at the eastern end of the island of St. Domingo. The observations were taken every two hours from 6 a.m. to 10 p.m. during 1886 and 1887; and at 7 a.m., 9 a.m., 2 p.m., and 9 p.m. during 1888. The following are some of the results for each year:—

Year.	Temperature.				
	Mean.	Mean Max.	Mean Min.	Highest.	Lowest.
1886	78°0	86°0	69°9	96°0 April 3	69°8 July 5
1887	77°2	85°4	69°0	.....	.....
1888	77°2	84°3	70°1	92°5 October 8	58°5 March 4
Year.	Sunshine.	Rainfall.			
	Hours.	Total.	No of days.	Greatest fall.	
1886	2801·4	ins. 91·96	160	ins. 6·00 April 4.	
1887	.....	65·73	...	5·50 May 16	
1888	2481·4	85·85	...	4·50 April 27	

METEOROLOGISCHE ZEITSCHRIFT. Redigirt von Dr. J. HANN und Dr. W. KÖPPEN. July-September 1890. 4to.

The principal articles are:—Zusammenfassung der Resultate der Barometer-vergleichungen von Waldo, Sundell und Brounow, 1883-87; von Dr. W. Köppen (12 pp.). This is a criticism of the results of these three comparisons of standard barometers, which were carried out between 1883 and 1887. It is satisfactory to learn that Dr. Köppen finds that the alleged differences between standard barometers do not exist, and that these instruments all fairly agree together.—Messungen des normalen Potentialgefälles der atmosphärischen Elektricität in absolutem Maasse; von J. Elster und H. Geitel (13 pp.).—Der Wolkenbruch auf der Kii-Halbinsel, Japan, am 19 August 1889; von E. Knipping (11 pp. and 2 plates). This is an account of a terrific fall of rain and consequent devastation by floods which was produced by a slow moving typhoon in the south of the Island of Nippon. At one station, Tanabe, 85·5 ins. fell in 17 hours; three other stations had about half that amount. The number of lives lost was 1,502, and 400,000 people were rendered homeless. The number of trees washed away in one district is estimated at 200,000.—Veränderlichkeit der Tagestemperatur in Japan; von E. Knipping (6 pp.). This discussion shows that the variability of temperature in Japan is moderate, as might be expected from its insular climate.—Ueber wandernde Funken; von F. von Lepel (4 pp.). This is an account of the reproduction of ball lightning, as already announced by Planté in the *Comptes Rendus* for 1875-6. Herr von Lepel has produced them by a simpler process, for which reference must be made to the paper. The appearance of balls indicates a very weak tension, a very slight increase of tension produces a red spark instead of a ball.—Ueber das allgemeine Windsystem der Erde; von W. von Siemens (8 pp.). This is an answer to some remarks of Dr. Sprung's, in the

form of a reprint of Siemens' paper in the *Sitzungsberichte* of the Berlin Academy. It is a purely theoretical paper showing how far the author agrees with Ferrel, or the contrary.—*Bemerkungen über die Temperatur in den Cyclonen und Anticyclonen*; von Dr. J. Hann (16 pp.). This is a very convincing reply to the utterances of Prof. Hazen in *Science*, who has asserted that all Dr. Hann's statements as to the distribution of temperature with height in mountains are worthless. Dr. Hann, by careful reasoning, shows up Prof. Hazen's mistakes.—*Die Veränderlichkeit der Temperatur auf den britischen Inseln, 1869-1888*; von R. H. Scott (8 pp.). This is an abstract of Mr. Scott's paper in the *Proceedings of the Royal Society* on the variability of temperature.

PROCEEDINGS OF THE ROYAL SOCIETY. Vol. XLVIII. Nos. 292-294. 8vo. 1890.

Contains: On the barometric oscillations during Thunderstorms, and on the Brontometer, an instrument designed to facilitate their study: by G. J. Symons (9 pp.). During some heavy rains and during some thunderstorms, the barometer rises and falls rapidly and irregularly. In order to ascertain the cause of these variations, the author considers it necessary to determine precisely the sequence of the various phenomena, and the times of their greatest intensity, and for this object he has devised in conjunction with MM. Richard Frères, of Paris, the instrument which he terms a Brontometer, or Thunderstorm measurer. This is provided with endless paper, 12 ins. wide, travelling under the various recording pens at the rate of 1.2 in. per minute, or 6 ft. per hour. The velocity of the wind is continuously recorded by one of Richard's anemo-cinematographs, and the atmospheric pressure by a modified form of their statoscope, which is so delicate as to give 80 inches for each inch of the mercurial barometer. There are mechanical arrangements whereby the observer records: (1) the commencement, variation in intensity, and termination of rain; (2) the instant of each flash of lightning; (3) the commencement and duration of each clap of thunder; and (4) the commencement, variation in intensity, and termination of hail.—On Wind Pressure upon an inclined Surface; by W. H. Dines (25 pp.). This is an account of some experiments made on the large whirling machine at Hersham, somewhat after the plan indicated in Mr. Dines's papers on p. 205 of the present No. of the *Quarterly Journal*.

SYMONS'S MONTHLY METEOROLOGICAL MAGAZINE. Vol. XXV. Nos. 294-296. July-September 1890. 8vo.

Contains among other information the following articles:—Areas of rarefaction or Depressions: by the Rev. G. T. Ryves, Dr. Muirhead, Prof. Hazen, and W. H. Dines (7 pp.).—The great rain of July 17th, 1890 (1 p. and map.).—Phenological Observations (1 p.).—Solar radiation thermometers; by Prof H. McLeod (2 pp.).—Sunburn (3 pp.).—The Climate of Brighton; by F. E. Sawyer (2 pp.).

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QUARTERLY JOURNAL
OF THE
ROYAL
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634 $\frac{25}{2}$

EDITED BY
A COMMITTEE OF THE COUNCIL.

VOL. XVII.

1891.

LONDON:
E. STANFORD, 26 & 27 COCKSPUR ST., CHARING CROSS, S.W.;
WILLIAMS AND STRAHAN, 7 LAWRENCE LANE, E.C.
1891.

LONDON :
PRINTED BY WILLIAMS AND STRAHAN,
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ERRATA.

Page 19, line 7 from bottom, *after* the word "open " *insert* "and three rooms high, on the side struck."

Page 154, line 19, *for* 12 *read* 1.

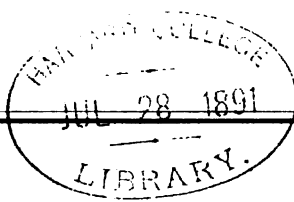
„ „ „ 8 from bottom, *for* 116 *read* 216.

„ „ „ 8 „ „ „ mean *read* maximum.

„ „ „ 2 „ „ „ 990 *read* 900.

Vol. XIII. p. 807, line 16, *for* Dines *read* Owen.

„ XVI, p. 225, „ 22 from bottom, *for* 1·2 *read* 1·9.



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Quarterly Journal
OF THE
**ROYAL
METEOROLOGICAL
SOCIETY.**

EDITED BY A
COMMITTEE OF THE COUNCIL.

JANUARY 1891.
VOL. XVII. No. 77.

LONDON:
EDWARD STANFORD, 26 & 27 Cockspur St., CHARING CROSS, S.W.;
WILLIAMS AND STRAHAN, 7 LAWRENCE LANE, CHEAPSIDE, E.C.

Price Five Shillings.

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ESTABLISHED 1850. INCORPORATED BY ROYAL CHARTER, 1866.

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APRIL	15	,,	DECEMBER	16	,,

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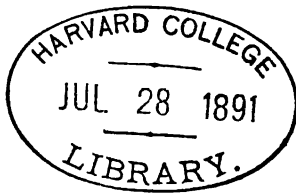
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QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY.

VOL. XVII.

JANUARY 1891.

No. 77.

THE RELATION OF GROUND WATER TO DISEASE.

An Address delivered to the Royal Meteorological Society, November 19th,
1890.

By BALDWIN LATHAM, M.Inst.C.E., F.G.S., F.S.S., F.S.I., &c.,
PRESIDENT.

(Plates I.-IV.)

THE work in which the Fellows of the Royal Meteorological Society are engaged is one of surpassing importance, as regards the study of the causation of disease. The words written by John R. Arbuthnot, M.D., F.R.S., more than a century and a half ago, are probably as applicable now as when written. He said "a history of facts or a journal of diseases compared with the weather, which, if it should be kept for any great period of time and in many places I will venture to affirm that mankind would arrive at more than a conjectural knowledge in this matter. The ancient physicians seem to have been more attentive to this than the moderns, and those of the moderns who have attended to it have perhaps made no inconsiderable figure in their profession."

Various climatic conditions affect disease; and to get at the particular influence of any one condition it is necessary to differentiate between various causes. The variations in climatic condition are extremely diversified, and the study of their influence on disease should not extend over too great an area; for it is only in typical years that their influence is wide-spread.

In studying the effects of underground water on disease, we must care-
NEW SERIES.—VOL. XVII.

A

fully eliminate those other agencies which are known to have an influence upon health. The pages of history show that when the ground waters of our own or other countries have arrived at a considerable degree of lowness, as evidenced by the failure of springs and the drying up of rivers, such periods have always been accompanied or followed by epidemic disease.

I may say, at the outset, that in the study of this subject it will be found, in all probability, that ground water in itself, except under conditions where it is liable to pollution, has no material effect in producing or spreading disease. As a rule it is only in those places in which there has been a considerable amount of impurity stored up in the soil that diseases become manifest, and the most common mode by which diseases are disseminated is by means of the water supplies drawn from the ground, or by the introduction of contaminated ground air into the habitations of the people. It will also be found that the periods of low and high ground-water mark those epochs when certain organic changes take place in the impurities stored in the earth, and which ultimately become the cause, and lead to the spread, of disease.

For the purpose of illustrating the influences of ground water upon health I propose to deal more especially with the records of Croydon; not because Croydon is an exceptionally unhealthy district, for it is a district extremely favourable to health by reason of the comparatively recent extension of its population over a maiden soil which has not had time to be polluted by the residence of man upon it. In fact, if you wish to get the true significance of the bearing of climatic influences on health, you must go into those districts which have been long occupied by man as residences, in which the ground has received from year to year considerable accessions of pollution. On this account the observations made at Croydon are unfavourable, but what occurs there is accentuated in other districts not so favourably located. We have, moreover, in Croydon a comparatively perfect register of Baptisms and Burials, going back to the year 1589.

For years past I have been carrying on observations upon the state of the ground water within and around this particular area, with a view of discovering the influences which affect the health of the place, and by inference of all other places. I have had extracted the date, the place, and the cause of every death since registration has taken place, and have also had abstracted the whole of the burials, separating them to each month of every year. The Croydon Register of Burials shows that the incidence of disease in Croydon three hundred years ago did not differ greatly from what is observed at the present time.

Croydon is also by no means a favourable place for the study of certain types of disease, owing to the fact that it has been subject at certain periods to various epidemics, the protective influences of which against a second attack of such disease tends to obscure the law that governs their extension.

One of the climatic conditions which affect health is that of temperature. Heat and cold have a marked influence in producing disease. The month of June is the most healthy month of the whole year. As we leave the point of mean temperature, either on one side or the other, the death rate increases, but from a different class of disease.

The following table shows the death rates in Croydon. In it I have shown the mean temperature of the months of December, January and February

COLD AND HOT PERIODS WITH DEATHS¹ IN CROYDON.

Year.	Temp. Dec. Jan. Feb.	Death Rate, Jan. Feb. March.	Deaths of Children under 5 years of age, Jan. Feb. March.	Temp. June, July, Aug.	Death Rate, July, Aug. Sept.	Deaths of Children under 5 years of age, July, Aug. Sept.
1837	40°5	39·8	..	60°9	28·5	47
1838	39°1	33·7	51	60·2	31·5	55
1839	39·8	22·3	28	60·3	23·3	35
1840	40·4	23·4	31	59·2	23·9	34
1841	34·6	29·1	41	58·2	18·4	28
1842	38·1	31·0	56	62·8	24·1	35
1843	40·3	25·0	29	59·8	21·1	36
1844	39·4	21·8	33	60·0	16·4	22
1845	34·7	23·5	26	59·2	20·0	26
1846	43·1	20·0	32	64·3	18·8	34
1847	34·7	28·3	47	61·8	28·7	56
1848	40·2	33·5	88	59·9	25·6	32
1849	43·0	31·6	47	61·1	31·8	34
1850	39·0	18·2	33	61·7	19·4	30
1851	41·1	19·3	42	60·9	26·0	40
1852	41·3	20·6	44	61·7	22·2	41
1853	40·6	36·8	73	60·1	22·1	33
1854	37·7	24·3	61	59·4	27·6	62
1855	35·3	26·3	48	61·1	18·4	44
1856	39·2	19·1	51	61·5	17·5	36
1857	38·7	18·8	46	64·0	16·1	49
1858	39·5	18·6	35	63·1	18·6	57
1859	41·7	18·4	34	65·0	25·1	91
1860	36·7	18·7	57	57·4	14·8	33
1861	39·1	19·4	46	62·0	16·0	55
1862	40·9	20·9	66	58·6	14·2	40
1863	42·7	20·7	67	61·3	22·2	78
1864	38·8	29·9	112	60·4	18·5	70
1865	37·4	22·1	82	62·3	21·6	97
1866	42·6	27·5	125	61·1	17·8	78
1867	40·8	22·1	90	60·5	16·8	73
1868	39·6	22·1	105	65·1	25·0	141
1869	44·1	21·7	99	60·2	23·4	135
1870	34·1	20·8	105	62·5	20·2	130
1871	35·8	22·6	133	60·4	22·4	127
1872	41·5	19·5	119	61·7	19·5	126
1873	39·8	17·7	93	61·7	15·7	111
1874	40·3	17·8	101	60·9	15·4	110
1875	37·2	22·1	112	60·3	18·8	125
1876	38·9	21·4	121	62·7	19·9	143
1877	43·7	20·0	130	62·0	15·0	93
1878	41·3	18·0	117	62·0	18·9	164
1879	34·6	21·6	127	58·5	12·9	88
1880	36·0	24·3	130	60·6	24·2	153
1881	37·7	17·7	110	61·2	16·6	149
1882	40·8	21·2	190	59·0	16·3	134
1883	41·5	16·2	117	60·3	12·1	94
1884	42·2	17·7	145	62·1	17·3	171
1885	40·6	19·8	154	60·6	16·3	121
1886	36·3	17·7	126	61·0	15·3	153
1887	36·6	16·0	118	62·8	15·2	143
1888	36·7	16·6	113	58·6	10·8	83
1889	33·3	16·0	126	61·1	13·7	126
1890	38·8	22·2	192	59·6	14·7	142

¹ From Burials.

compared with the number of deaths in January, February and March, and the mean temperature of the months of June, July and August, and compared with it the deaths in July, August and September.

During the period included in this table the population of Croydon has increased from 14,885 in 1837, to 79,615 in 1881, and the population is now estimated by the local authority at over 100,000, a figure, however, which in my judgment is too high.

Although cold is shown to affect health, yet, in all probability, cold is not an important factor as affecting the health of children under five years of age. This has clearly been demonstrated by the fact that the death rate of children in cold countries, such as Norway, is absolutely less than that of England, while in a warm country like Italy the death rate of children is higher than that of England. This latter fact is doubtless partly due to the influences of high temperature, but in the study of the influence of ground water it is found that the deaths of children increase in a remarkable degree at the period of low ground water, and the death rate fluctuates in a singular manner compared with the variation in the annual amount of ground water, the rate being least with the highest and greatest with the lowest ground water. Consequently, if the ground water is plotted on a diagram with ordinates upwards, and the death rate with ordinates downwards, there will be found to be a remarkable parallelism between the lines.¹ We often have the lowest ground waters in the months of the lowest temperature, and, therefore, it becomes necessary to separate the influence of cold from that of lowness of ground water. This country has had the most unhealthy periods when the ground water has been at its lowest. The following table shows the death rates of England and Wales in the first quarters of the respective years, embracing all the known general low water periods that have occurred since the Registration of Deaths was established.

DEATH RATES, ENGLAND AND WALES, IN LOW WATER PERIODS.

First Quarter of Year.

Year.	Death Rate.	Temp. Greenwich.	Year.	Death Rate.	Temp. Greenwich.
1838	26.2	35.8	1864	27.7	38.1
1845	25.5	33.6	1865	27.0	36.8
1847	28.5	36.8	1866	26.2	42.0
1848	27.9	40.6	1875	27.5	39.6
1853	26.1	37.3	1885	22.0	40.2
1855	29.1	33.9	1888	21.2	36.9
1858	26.3	38.5	1890	23.1	41.4

If the death rates given in this table be compared with the average temperature of the period, it will be seen that there are other influences at work, apart from temperature, affecting disease and producing death, and it may be said with reference to these observations, that up to the year 1875 the

¹ This is shown in Plates 1 and 2.

mortality of England and Wales in any quarter of the year (with the exception of the September quarter of 1849, when cholera was rife¹) was at these particular periods of low water greater than at any other time.

It is well known that heat and cold limit the area of particular diseases, and that the temperature of the ground has also an essential bearing on the causation of disease. Heat has also a tendency to reduce ground water, and, on the other hand, intense cold has a similar effect, as in time of frost the surface waters are frozen and percolation is stopped.

In the study of this question, we must also bear in mind that the amount of light has a material effect on disease. The healthiest months of the year are those in which the sun is for the shortest period below the horizon; the unhealthy periods are those in which there is the longest period of darkness. It has been well said that "pestilence walketh in darkness," and this is undoubtedly true, for, at present, we know but little of the causation of disease. The period of greatest darkness is also that of the greatest amount of percolation of water through the soil, as it is found that many diseases increase during the percolation period and decline as percolation ceases, so that there is a parallelism between the periods of darkness and percolation. It is well known that in malarious countries, malaria is most active at night, and districts which can be traversed with impunity in daylight become dangerous after sunset. We have also the experience furnished by Arctic Expeditions. H.M.S. *Assistance* was 94 days in winter darkness in the Arctic regions in the Expedition of 1850-51, and when the health of its crew is compared with that of the *Alert*, in the last Arctic Expedition, which was 142 days in polar darkness, it was found that scurvy was very much more rife in the ship the longer exposed to the influence of darkness, although both vessels were on an equality with regard to provisions and other matters.

Dr. Macnamara has observed in India that cholera cases were always most numerous when the sky was overcast, and in this country it has been observed that more deaths take place while the sun is below the horizon than when it is above the horizon. We must, therefore, in studying this question make allowance for the periods of darkness, and must eliminate this as a probable source of error in judging of the influences of ground water. When the question of epidemic disease is studied, it will be found that the black death of the 14th century, the sweating sickness of the 16th century, the plague of the 17th century, and in modern times cholera, typhoid fever, scarlet fever, dysentery, diphtheria, all follow the same track, having the same seasonal fluctuations. We may, therefore, look to some common cause favouring the development of these particular diseases.

In studying the question of disease, we must also bear in mind that the conditions which affect mankind also influence the health of cattle. When this is more generally known, probably greater attention will be paid to the means of preventing loss amongst the stock of the country, even if the health

¹ I am not certain that in these years the population of the country was not over estimated, and that it consequently appears to be more than was really the case. The ground water was certainly not so low as in other years given in this table.

of man is neglected, for it is curious in an enlightened country like England, in which sanitary science has had its origin, that a Minister of Agriculture, who looks after the health of the cattle, should be appointed before we have a Minister of Public Health for the population.

Disease is undoubtedly more potent and strongly marked amongst the young. Now it would be impossible in the course of such a paper as this to draw attention to the influences connected with every disease. I, therefore, only propose to direct your attention more particularly to what are known as zymotic diseases, the general death rate, and the mortality of children under 5 years of age.

The question may be asked, What is ground water? The answer is, All water which is found in the surface soil, except such as may be in chemical combination with the materials forming the crust of the earth. It is mainly derived by percolation from rainfall; the ground becomes wetted, and when fully saturated in porous soils, water passes through and lodges in the lower portion of the strata and becomes the free water which we measure in wells in order to ascertain its relative height from time to time. Ground water is also produced by condensation: whenever the ground is colder than the air, a certain amount of vapour is condensed within the pores of the surface of the soil, and this is partially given off at those times when the soil is warmer than the air, especially at night. In dry countries ground water is principally supplied by the infiltration from rivers, as for example in the Delta of the Nile. In some strata, the whole of the ground water is held by capillarity, as in clay and other soils and in rocks of close texture, whilst in others it is held both by capillarity and as free water, and this ordinarily is termed the ground water. The free ground water may be increased by water passing from the superincumbent strata, in which it is held by capillarity, even without rain, as in the case of a rapid fall of the barometer. The free water of the ground is a very active agent, and may become the direct vehicle for conveying to unlimited distances the active properties of disease. This free ground water rises and falls, as a rule, every year, forming a wavelike profile, when plotted as a curve, the rise being much more sudden than the fall. It is also always moving in particular directions. As a rule it moves in the direction of natural outlets, which may be either the sea, springs or rivers; its greatest amplitude of fluctuation is at the most distant point from its point of escape, while its least range of fluctuation is close to the point of discharge. As a rule, when there is a large quantity of water in the ground a large quantity is discharged, and *vice versa* with small quantities. It should be noted that most of our old cities and towns are located upon porous soils in which usually there has been water in the subsoil. This has, no doubt, been often done as a matter of convenience for the water supply, and in those periods when such underground waters were exclusively relied upon to furnish a supply of water to the inhabitants, epidemics and diseases of various kinds were very much more rife and fatal than at the present time, when in the principal towns of the country such sources of water supply have been abolished. The mechanical effect of rain passing into the ground has

also an influence in disseminating disease, because the ground always contains air, and the rainfall cannot occupy the space previously occupied by this ground air without expelling it. This air more readily escapes into our houses, the porous passages to which are left open, being protected from the influence of rain, while those outside the house are sealed by the falling rain. On the other hand, all the time that the ground water is diminishing there is a tendency for air to be drawn in to occupy the space formerly taken up by the water. Upon investigation, it will be found that diseases of a certain type are most rife during the period that the ground is filling up with water and expelling the ground air, and are least prevalent when the current of air is inwards instead of outwards from the ground. Of course these conditions are also subject to variation with the changes of barometric pressure. As a rule, the amount of free water in the ground cannot with accuracy be estimated by the quantity of rain, as the quantity entering the ground depends upon its hygrometric condition; however, in the absence of other information, the state of the ground water may be often inferred from rainfall records. In some years it is found that the actual amount of rain which may enter the ground at a particular period, as measured by percolation gauges, may be considerably less than that flowing off; for if the ground waters are very low, probably more will enter the ground than flow off in the same year. As an example, in the year 1886, after the low waters of 1887, but 7 ins. were known to have flowed off the Croydon Drainage area of the River Wandle, while over $18\frac{1}{2}$ ins. percolated through a chalk gauge in the same year. Again, in the year 1887, only 5 inches of rain passed through the percolating gauges, while in that year nearly 9 inches flowed off, the balance being drawn from the store previously left in the ground. In some years there is no low water, but these are exceptional periods. However, the records from a well at Hartlip Place, near Sittingbourne, show that in the year 1829 there was no low water, the water rose all through that year up to June 1830, and this was a healthy year. In some districts, the fluctuation in the ground water has considerable amplitude. It is not unusual to find wells in which the water line may within a few months vary over 100 feet between the highest and lowest levels. On the other hand, in certain seaside places and towns located near rivers the fluctuation is very small, and as a rule the healthiest districts are those where there is the least vertical rise and fall of the subsoil water, and this is the case in nearly all seaside health resorts. There are also examples when an undue elevation of the free ground water, beyond what is ordinarily its normal range, may produce all the effects which are noticeable after low water periods. Professor Pottenkofer, in his observations at Munich and elsewhere, established beyond doubt the coincidence of cholera and typhoid fever with low ground water. If we direct our attention to American experience, we find the Reports of the State Board of Health teeming with information upon this very point, and Dr. Draper says with reference to Massachusetts, that the charts show that enteric fever, cholera, diarrhoea and dysentery, are more prevalent when springs are low than at other periods of the year. Investigations conducted by Dr. G. Buchanan

and Mr. W. Whitaker, F.G.S., in 1867, on phthisis in this country,¹ show that an excess of water in the soil increases the death rate from that disease. It may be said with regard to all the epidemics of typhoid fever in this country that, without exception they occur immediately after the periods of the lowest water, and as a rule typhoid fever occurs at periods of the year when the waters are generally low, and on the rise of the water, usually in the autumn.

We know that the germs of disease can be carried a considerable distance underground through the soil by the movement of the free ground water, as shown by the experience at Lausen in 1872. I can also point out a case in my own experience in a chalk district in Yorkshire occurring within the present year, where polluted water has travelled underground a considerably greater distance than in the case of Lausen, and has produced typhoid fever.

In some districts, the number of disturbances or rises and falls in the sub-soil water have a marked influence upon health; for example, if the health statistics of Chichester are compared with the long record of the well at Chilgrove near that city (the observations in connection with which have been carried on by Mr. Thomas Wood and his father), it is found that the greater number of disturbances which have occurred in the Chilgrove well mark the most unhealthy years within the city of Chichester. The year 1888 may be taken as a recent example, when there were three distinct rises and falls in the water of this well in this particular year, and the proportional mortality in Chichester was the highest recorded in the last 20 years.

That the earth itself does exercise a baneful influence on health has been well exemplified by the statistics referring to the unhealthiness of cellar dwellings, which have also established the fact that ground floors, as a rule, are not so healthy as the upper rooms of our habitations.

The absence of water passing into the ground for a long period naturally leads to the lowering of the free ground water line, and may lead to the drying of the ground above the water line; and it is curious to note with reference to small pox that the periods preceding such epidemics of small pox are those in which there has been a long absence of percolation and consequent drying of the ground. On the other hand, small pox is unknown at periods when the ground has never been allowed to dry, or is receiving moisture by condensation or capillarity. The nature of the soil affects the results, as in percolating gauges it is found that all soils will not record the particular conditions of dampness which are favourable to some diseases.

It should also be noted with reference to the effects of ground water upon disease that these conditions may be often artificially produced. It is curious to note in the first epidemic of typhoid fever in Croydon in 1852, that previous to its outbreak the ground water had been artificially lowered under the town 6 feet by the destruction of a mill dam and the construction of a sub-soil drain for the express purpose of lowering the ground water, and it is also curious to note that Dr. Neill Arnott, who reported upon this particular epidemic at Croydon, gave, in his report, an instance which occurred in the

¹ "Report by Dr. Buchanan on the Distribution of Phthisis as affected by dampness of the Soil." *Tenth Report of The Medical Officer of the Privy Council*, 1867.

year 1825, where, after the construction of a sewer and the drying of the ground, which was marked by the drying up of the ponds in its particular neighbourhood, an outbreak of typhoid fever occurred. It is a matter of common experience that in all old towns formerly ramified with cesspools, and often deriving their drinking water from local wells, it is not at all infrequent when works of drainage are first introduced having a tendency to lower the subsoil water, for typhoid fever and other diseases to occur, and this is not unusually ignorantly attributed to the new system of sewerage.

We possess in this country a number of records with regard to the height of the ground water, and these records are multiplying yearly, so that probably, when the importance of this question is more appreciated, we shall have a further increase. The registration of deaths in this country only commenced in July 1887. We have in many parts of the country complete records of underground water which carry us back beyond the date when registration of deaths commenced, and by comparing the records which we now possess with the registrations of deaths, we are able to show that the relative height of the ground water has a material bearing on mortality. It would be impossible, in the limits of an address of this kind, to particularise all the various diseases which are influenced by underground water. I trust the information about to be given will furnish some useful material to any person desirous of studying its influence on any specific disease. I may, however, point out to those who are ignorant of the fact, that an investigation of this kind has been made in the case of London and New York by Dr. Buchan, and Sir Arthur Mitchell, M.D., and the published diagram of London mortality shows at a glance the incidence of every class of disease which has occurred during a period of many years. It will be apparent to any one who will study this document that certain diseases have their allotted seasons and conditions under which they are more or less rife.

The study of underground water shows that certain diseases are more rife when the water is high in the ground, and others when the water is low. The conditions that bring about and accompany low water, however, have by far the most potential influence on health, as all low water years are, without exception, unhealthy. As a rule, the years of high water are usually healthy, except that it often happens when high water follows immediately upon marked low water, that on the rise of the water an unhealthy period follows. This has been already referred to and pointed out in the tables, which show the very high death rates in the first quarter of all years following marked low water periods. The most unhealthy periods are those which indicate the first passage of water through the ground. Periods such as these are indicated by Dr. Arbuthnot, when he wrote "The surface of the earth being by drought first shut up and afterwards opened by rain." He also pointed out what is found to hold good in modern times, that the breaking up of frosts was followed by the commencement of epidemic disease, and he specially mentions the conditions previous to the plague of London as being very singular, in a sudden thaw, breaking out after a hard winter frost, lasting till nearly the end of March, and the ground covered with water from melted snow, while ice and great heat succeeded.

Many epidemics, especially of cholera and typhoid fever, have been traced to particular rainfalls. The remarkable correspondence between rainfall and fever is shown by the diagrams of the outbreak of typhoid fever in Paris in 1882. The majority of the zymotic diseases follow the period of percolation and are most rife in the year of lowest water.

Low water years are also as dangerous to cattle as to man. The year 1714 was a remarkably dry year, when only 11·19 inches of rain were recorded as falling at Upminster. In that year the burials in Croydon were more than double those of the preceding year, and in London the burials rose from 21,057 in the preceding year to 26,569 in this particular year. Another dry year was 1742, when 15·7 inches of rain were recorded at Lyndon. In that year the burials in Croydon were almost three times as numerous as in the following year, whilst the burials in London were 92,169 as against 27,483 in the following year. In both these years much cattle died from murrain.

There have even been greater periods of drought recorded than in the years mentioned; and without exception they have exercised a baneful influence, so, in modern times, the periods of drought mark the periods of disease. On the other hand, wet summers are usually healthy. Those years in which there has been no low water are those in which health has been invariably good. In the year 1829 the records of the well at Hartlip Place show that there was no low water at the usual period in that year. The waters rose continuously through the year up to June 1830, and so; too, with other years in modern times, such as the years 1860 and 1879 when a similar state of things existed, and these are all healthy periods.

We must also bear in mind, in studying these questions, that the rates of mortality are, by no means, so reliable as the rates of sickness. Unfortunately, however, in this country we have not the rates of sickness at present available. In Japan, however, there is every year recorded both the number of cases arising from certain zymotic diseases, as well as the number of deaths taking place, and as the seasonal variation of temperature in Japan is almost identical with that of our own country, we can observe in that country the influences of climate upon particular diseases. So, also, in countries in which there is a chronic state of dryness, as in Egypt, it is found that the health is materially influenced by the height of water in the ground. A low Nile marks an unhealthy period, and the most unhealthy times occur while the ground is filling up with water. For example, at Cairo, the average height of the Nile for 6 months, from January to June 1888, was 18·89 metres, when the death rate was 43·1; in the same period in 1889 the average height of the Nile was 18·5 metres, and the death rate was 49·1.

It will also be found, in studying this subject, that the districts which draw their water supplies direct from the ground are usually most subject to epidemics, and disease is much more marked there than in districts in which the water supply is drawn from rivers supplied from more extended areas, or from sources not liable to underground pollution. In the case of Croydon one portion of the district (under three-fourths) is supplied with water taken

direct from the ground, whilst the remaining portion is supplied with water from the River Thames. It is curious to note that, even so recently as 1885, the zymotic death rate in the districts supplied with underground water was twice as great as in that part of the districts supplied from the Thames, and in this particular year 41 deaths from small pox occurred in the district supplied by underground water, not one of which is recorded outside that district.

Cholera.

I propose now to deal with the zymotic diseases as affected by ground water, beginning with cholera. Cholera is known to attack with the greatest virulence places of low elevation, the very sinks of impurity. These places have to contend not only with their own local impurity, but with the pollutions which are carried by the movement of the ground water from places at a higher altitude into them. Cholera ordinarily breaks out when there is the least ground water, and a high air and ground temperature is also necessary for its development. As a rule, the low positions are favourable to the production of these high temperatures. Dr. Macnamara says, with regard to cholera, it is more rife in low alluvial soils, and it advances from east to west, or it advances exactly in the direction from the least to the greatest recorded falls of rain, and, as a consequence, just in proportion to the lowness of the ground water, which will be first lowest in the eastern districts and last lowest in the western districts. It has also been observed that cholera follows rainfall. After the drought in India of 1860, followed by rain in 1861, cholera broke out, and it has been observed by Dr. Macnamara and others that rain is connected with the development and dissemination of cholera poison, and that in India no wide-spread epidemic can occur unless during or after rain; but, on the other hand, it has also been noted that excessive rains will remove the disease, probably by rapid percolation and the cleansing of the soil from the germinal matter, or by producing a state unfavourable to the development of the germs. It should be noted, with reference to the epidemics of cholera in this country in 1832, 1847, 1854 and 1865, that these periods were all years of low ground water.

The following table (p. 12) shows the incidence of cholera and small pox in Calcutta for 26 and 29 years respectively.

It is curious to note the marked parallelism between small pox and cholera in India. But this parallelism between these two diseases is not confined to that country, nor to those diseases only. In Japan, where the seasonal variation of temperature occurs at the same period of the year as with us, but has a greater amplitude, they have for six of the zymotic diseases a registration of sickness; and an examination of these sickness returns shows the same results as in India. The second table on page 12 shows the rates of sickness in Japan for a period extending from 1879 to 1887, the population of the country being estimated at a little over thirty-nine millions in 1887.

TABLE SHOWING DEATHS FROM CHOLERA FOR 26 YEARS, AND FROM SMALL POX FOR 29 YEARS IN CALCUTTA.—COMPILED BY DR. MACPHERSON.

Month.	Cholera, Total Number of Deaths.	Small Pox, Total Number of Deaths.	Rainfall.	Average Tempera- ture.	Range of Tempera- ture.	Prevailing Winds.
			Ins.	°	°	
January.....	7150	1425	0.21	63.4	17.9	N NE NW
February	9346	2845	0.42	74.2	17.3	N NE NW
March	14710	4934	1.13	82.9	16.3	W SW S
April	19382	4249	2.4	86.6	14.7	S WSW
May	3335	2261	4.29	89.0	13.3	S S W
June	6325	1054	10.1	86.2	9.0	S S W
July	3979	555	13.9	84.0	6.4	S SE SW
August	3440	223	14.4	82.6	5.2	S SE SW
September.....	3935	188	10.4	83.8	6.6	S SW W NW
October	6211	147	4.72	81.1	8.8	W S N NW
November	8323	132	0.90	75.4	14.2	N NE NW
December	8159	576	0.13	66.9	16.4	N NE NW

JAPAN.—INFECTIOUS AND CONTAGIOUS DISEASES.

Year.	Cases of Cholera.	Cases of Small Pox.	Cases of Typhoid Fever.	Cases of Diphtheria.	Cases of Dysentery.	Cases of Typhus.
Jan. 1879 to June 1880 ..	162637	4799	10052	1280	8169	2341
July 1880 to June 1881 ..	1580	3415	17140	1838	5047	1527
July to December 1881 } (6 months)	9389	342	16999	1107	6827	564
1882.....	51631	1105	19308	2028	4330	629
1883.....	969	1271	18769	2307	21172	412
1884.....	904	1703	23279	2237	22702	3459
1885.....	13824	12759	29504	2798	47377	2302
1886.....	155923	73337	66224	3265	24326	8225
1887.....	1228	39779	47449	2741	16149	2487

It should be noted that cholera, as a rule, has not the same monthly incidence as small pox. The question of high temperature, which materially affects cholera, would appear to have, if it has any influence, the contrary effect upon small pox as upon cholera, after the conditions preceding its outbreak have been established. While the general conditions of ground water which bring about cholera also bring about small pox, the climatic conditions that accompany these diseases are of an opposite character.

Small Pox.

The true significance of small pox must be studied probably not so much with respect to our time as to periods gone by, when it was very much more fatal. It is, therefore, interesting to note that Dr. John Arbuthnot stated with reference to small pox, that he found that it was most fatal during hard frosts and cold North-easterly winds. Small pox is always preceded by a long period of dryness of the ground, measured by the absence of percolation. It should be noted that with reference to the year 1871, which was a very fatal

year, the smallest amount of percolation on record occurred. The register at Apsley Mills shows that but 1.36 inches of water passed into the ground in the whole of that year, and so it has been with other years, for, taking the Croydon records, it will be found in the autumn of 1870 small pox commenced in Croydon after a very dry period, and continued up to the autumn of 1871. In 1876 an outbreak again occurred after a very dry period, and continued until the autumn of 1877, and exactly the same conditions accompanied the outbreaks of 1881 and 1882, 1884 and 1885. It is quite clear that small pox only occurs after intense dryness of the ground. Since September 1885 there have been no deaths from small pox recorded in Croydon, but during the whole of that period (5 years) there has been but one month when no measurable quantity of water percolated through a gravel percolating gauge 1 yard deep, and that was in October 1886, a period when the ground was naturally moist; but in 1884, when small pox last broke out, it was preceded by 7 months in that year when no measurable quantity of water percolated through the same gauge. Having regard to the relation which has been shown to exist between small pox and other zymotic diseases which are capable of being transmitted by water and are propagated by unsanitary conditions, it is almost absolutely certain that small pox is propagated and disseminated in the same way as cholera and other diseases under the peculiar climatic conditions to which I have drawn attention.

Typhoid Fever.

The conditions affecting typhoid fever are capable of definite statement. The disease is most prevalent after a dry time when the first wetting of the ground or "percolation from any cause" takes place. The quality of the ground water does not appear to have any influence upon the disease, as shown by Professor Pettenkofer, yet all authorities agree that this is largely disseminated by well and other waters liable to contamination at low water epochs. Typhoid fever is always more rife while the waters are rising in the ground than when they begin to diminish. In the first great epidemic of fever in Croydon, in the autumn of 1852, which occurred with a very rapid rise of the subsoil water, and also after the artificial lowering of the water to which I have already referred, it is established beyond doubt that the waters in this district had been remarkably low. In the 20th Volume of the *Proceedings of the Institution of Civil Engineers*, page 199, attention is drawn to the fact that in this particular year the supply of water in the River Wandle (one branch of which rises at Croydon) was so deficient, that the mills were compelled to be shut down three hours out of every twelve, and that there was still a deficiency of water. The low water periods which occurred in 1854 are well authenticated, for this particular year was universally a low water year. In 1858 there was another low water period, not, however, so low as the year 1854. In 1865 and 1866 there was a further epidemic of typhoid. Preceding this epidemic the Croydon branch of the River Wandle was known to have been absolutely dry, and in 1875 and 1876 was the last great epidemic, when again it was reported that the Croydon branch of the

River Wandle was dry. Since that period no such degree of lowness of the springs has been experienced at Croydon, and the sanitary works executed since that period have, in my judgment, added much to the healthful condition of the place.

I must now direct your attention to the distribution of the cases of fever which occurred in the last epidemic at Croydon, and shall compare them with the conditions which accompanied the epidemic of typhoid fever in Paris in 1882. Dr. Buchanan, in his report upon the outbreak of typhoid fever in Croydon in 1875, gives the distribution of cases throughout each month of that year. The epidemic, however, continued through 1876. The figures of 1875 show that there were two periods within that year when the disease was at maximum intensity, namely, in April—a most unusual period—and in October, the disease occurring in the spring of 1875 at a much later period than that at which the ground waters ordinarily commence to rise. The cause of the outburst at this period of the year is clearly demonstrated, as it occurred on the rise of the ground water, which rise had been delayed to the period when the disease eventually occurred, as is shown by the records of the state of the ground water within the higher portions of the Croydon drainage area, and which show that, after a very low water period, the waters began to rise in November 1874, and were rising up to March 1875, when they fell, rose slightly in June, then fell and rose again between September and October; there was a fall in November and a rise again in December. The following table shows the height of the water in the well at Caterham Lunatic Asylum, located near the head of the Croydon Drainage Area, at the dates given, together with the number of cases of fever occurring in 1875 and the deaths from fever in the three last months of 1874, through 1875 and the four first months of 1876.

WATER LEVELS IN WELL AT LUNATIC ASYLUM, CATERHAM AND FEVER IN CROYDON.

Year.	Date.	Level of Water above Ordnance Datum.	Date.	Reported cases of Fever in Month.	Deaths from Fever at Croydon.
1874	23 October	228.03	October	No record.	—
	5 November ..	232.53	November	"	—
	5 December....	238.53	December	"	1
1875	2 January ..	260.53	January.....	15	1
	1 February	287.53	February	53	1
	2 March	300.03	March	79	4
	1 April.....	295.53	April	186	13
	1 May	276.03	May	39	10
	1 June	280.03	June	30	8
	1 July	268.03	July	18	4
	1 August	264.03	August	32	3
	2 September ..	260.03	September	69	5
	2 October	261.03	October	275	15
	5 November ..	257.03	November.....	92	19
	1 December....	288.03	December	71	6
1876	1 January	290.53	January	No record.	10
	1 February	291.03	February	"	9
	1 March	294.03	March	"	8
	1 April.....	312.03	April	"	2
	2 May	304.03	May	"	—

It should be noted that the water in Croydon itself, which is some miles lower down the valley, would not ordinarily begin to rise until a later period than the waters in this particular well.

In Paris, in 1882, an exactly similar state of things occurred; an epidemic of fever broke out, as shown by the records published by the late M. Durand Claye, C.E., after a slight rise in the ground water. All the outbreaks of typhoid fever which have been investigated in this country have occurred under similar conditions. As a notable example, the outbreak which occurred at Terling, a village having a population of about 900 persons, in which, between November 1867 and the 13th January 1868, there were 208 cases of typhoid fever. It is mentioned by Dr. Thorne, who inquired into this epidemic, that all the wells in this village had become dry previous to the outbreak of fever, and the disease made its appearance at a time corresponding to the first replenishment of the water in the wells, after being so exceptionally low. Since 1868 numerous recorded epidemics of typhoid fever have occurred, accompanied by exactly the same circumstances as regards the state of the ground water, and all the great epidemics of typhoid fever have occurred in years when the ground water was especially low.

There has been a considerable amount of evidence collected in Paris, and also in this country, showing that outbreaks of typhoid fever can be traced to particular dates of heavy rainfall, and clearly establishing the fact that rainfall is associated with these epidemics. Consequently, we are not surprised to find that there often exists a parallelism between rainfall and typhoid fever. In judging, however, of the effects of rain upon the subsoil, the direct measurement of a well will not give, as a rule, the first indication of the commencement of water percolating through the ground, for the simple reason that if the quantity passing through is very small, it has no appreciable effect upon the height of the water in the ground itself, for the ground water is like a reservoir which at certain periods receives water, but water is also flowing out of it and no increase will be visible in the store until the rate of supply exceeds the rate of depletion. When, however, we do perceive that there is a check in the rise of the waters, or they become stationary, we may conclude that percolation has commenced. It may also be a matter of considerable importance to note that in all the epidemics of fever which have occurred in Croydon the universal testimony has been that women, children, and testotals have suffered the most, and in Dr. Buchanan's report on the last epidemic of fever it is shown that out of every 1,000 houses in that part of the district supplied with water taken direct from the ground, 104 were invaded by the disease, but in the district outside this area, containing, at least, a fourth of the whole population of the place, only 7 per 1,000 were attacked.¹ The significance of these facts ought not to be ignored by all who are answerable for the public water supplies of our country.

Diphtheria.

Diphtheria, according to a communication made at the last International Con-

¹ Most of these cases were children attending the Board School at which ground water is supplied from Croydon.

ference on Hygiene at Berlin, like typhoid fever, is propagated by excremental poisoning of the ground, and we know it is disseminated almost in the same way as typhoid fever. We know that it follows typhoid fever in parallel lines, but the very opposite conditions are necessary for its development to those which occur with typhoid fever and small pox. A damp state of the ground, marked by extreme sensitiveness to percolation of rain, is the condition which is essential to the development of diphtheria. With typhoid, a dry ground is essential to development, as we approach one or other of these conditions, so diphtheria or typhoid supervene. Diphtheria follows typhoid in its incidence, and occurs in the percolation periods. In this country, diphtheria has not until recent periods been separately registered, for some years it was registered as a type of scarlet fever; and we have no record in Croydon of its existence before 1849. Since 1858, however, it has been recorded with some degree of regularity. During the whole of the last 5 years the ground at Croydon has been in a continual state of dampness, as indicated by the records of the percolation gauges, and during the whole of that period diphtheria has been more or less rife, and has been generally increasing throughout the country.

Scarlet Fever.

Scarlet Fever follows the state of the dryness of the ground, which is essential for its development, and it occurs in the percolation period. The conditions that precede small pox are those favourable for the development of this disease. Hence it is most rife in the years preceding small pox. Like small pox the dampness of the ground for any considerable period in any particular locality may check its development, or render it less virulent, but it is most rife in low water years.

Measles.

It is curious to note with reference to this disease that in Croydon it apparently follows the opposite law to that of typhoid fever in the years in which there have been epidemics of typhoid fever, as in 1852, 1864, and in 1875; when the conditions were favourable to the development of typhoid, there were no deaths, or very few, from measles. This disorder is least prevalent at the low water periods, and is mostly rife at and near high water periods. In this respect it follows the same course as small pox, and as a rule measles is most rife in a low water year, especially following another low water year.

Whooping Cough.

Dampness of the ground is an essential condition to the development of whooping cough. It is a disease which causes a large number of deaths, and has been particularly rife during the past five years, during which time there has been a marked dampness of the ground. It destroys, in Croydon, three times as many persons as small pox, and it is most rife and fatal in all those years when small pox is absent. It follows the percolation period in its incidence, increasing with percolation and diminishing as the waters in the ground subside,

Diarrhœa.

It is generally supposed that diarrhœa is almost entirely influenced by high temperature. There is no doubt whatever that high temperature has a marked influence in the development and spread of this disease, but by comparing the records of any particular years with the temperature, it must be observed that there are other influences also at work, and it is found that diarrhœa is generally more prevalent in a low water year than in other years, that is, that in a low water year with a very much colder temperature we get a very much higher death rate from this disease. For example, in Croydon in 1854, which was a very marked low water period throughout the country, the average temperature for June, July and August was $59^{\circ}4$. In the following year, the temperature of the same months was $61^{\circ}1$. In 1854, the deaths were over five times as numerous from this disease as those which occurred in 1855, very clearly establishing the fact that diarrhœa, influenced as it is by high temperature, is also amenable to the conditions which produce low ground water, and that the organic changes which take place at such periods in the ground affect all sources of water supply, the temperature of which, rather than the season, governs the course of diarrhœa.

Deaths of Children.

Whatever errors may exist as to the cause of death amongst children, there can be no doubt as to the ages at which children die. In comparing the deaths of children under 5 years of age with the state of the ground water, it is found that there is in Croydon an exact parallelism between the state of the ground water and the death rate of such children.

General Death Rate.

It should also be noted that the general death rate of a district is regulated by the state of the ground water, in the same way as the deaths of children, but in a less marked degree. Years of drought and low water are always found to be the most unhealthy.

In concluding this subject, I desire to impress upon you that the health of communities is influenced by the sanitary conditions under which they live. Diseases of a virulent type are producible by very opposite climatic conditions, but are always most rife and most fatal in those districts in which there is the greatest chance of the ground being polluted. It is essential for the conditions of a healthy life that the soil upon which we reside should be freed from all chance of pollution, and every step should be taken in this direction. In studying the causation of disease it is also important that very much more attention should be paid to matters referring to the hygrometry of the soil. One would like to see a considerable extension made in establishing percolating gauges, and that all Meteorological Observatories should possess such an instrument.

It is also essential, in the study of the cause of disease, that the registers of sickness, which are now required to be taken in many of our towns, should

be published in ample form every year by some authority, and should be available for the use of all investigators. I trust that what I have said may be of interest, and may be the means of getting enlisted into our ranks a larger number of observers, particularly those who can devote their time to the elucidation of the various meteorological conditions which affect the health of the nation.

NOTE ON A LIGHTNING STROKE PRESENTING SOME FEATURES OF INTEREST.

By ROBERT H. SCOTT, M.A., F.R.S.

[Received November 17th.—Read December 17th, 1890.]

On my recent visit to the West of Ireland, I learnt that a remarkably violent lightning stroke had occurred within the peninsula of the Mullet, in the barony of Erris, Co. Mayo, and I went to the spot to collect what information I could.

The occurrence took place January 5th, 1890, in a violent storm of wind. I did not visit the place until October 12th, so that I have for the most part only hearsay evidence to report. The locality is the fishing village of Tip, about one mile from Ballyglass Coastguard Station, on Broad Haven. The house struck belonged to Michael Moran, who with his wife were the sole inmates. It is a thatched cottage, one storey high.

At 10.30 p.m. January 5th, 1890, Moran was in bed, his wife was standing up. She heard a very loud clap of thunder, and called to her husband to get up. Immediately after she was struck down and stunned for a short time, a few minutes. The bedroom showed marks of the lightning on the walls in various places.

The next morning it was found that the kitchen adjoining the bedroom was not much damaged, but that the sitting room on the other side of the kitchen had been completely wrecked.

The grate was forced out of its setting and thrown across the room. Various marks were seen on the walls, and a hole was pierced through the wall opposite the head of a crowbar which was leaning against the wall in the adjacent workshop. The hangings on the mantelpiece, &c., were much torn; there were no signs of fire or fusion, except that two corners of a photograph on a metal plate standing on the chimney piece were fused; but the photograph itself was otherwise uninjured. All objects of glass or china in the room were upset, but only a few of them broken; a corner was cut clean off a glass ink bottle, without spilling ink, &c. The most extraordinary occurrence was what happened to a basket of eggs lying on the floor of the room. The shells were shattered, so that they fell off when the eggs were

put in boiling water, but the inner membrane was not broken. The eggs tasted quite sound. Moran's account is that he boiled a few eggs from the top of the basket, the rest were "made into a mummy, the lower ones all flattened, but not broken."

I have referred this latter statement to my friend, Mr. C. W. Boys, F.R.S., whose reply is as follows :—

"I can only conclude from your account of the destruction of the egg shells by the lightning, that the action was purely mechanical, the result of a detonation among the eggs, rather than electrical. I do not think the eggs within would have remained undamaged if the lightning had really struck them.

"It seems very similar to the result of an experiment which I have seen in which an egg thrown up in the air and falling on hard turf, was not broken, though no doubt the shell at the point of impact was cracked up a good deal.

"The egg was not boiled, for on being thrown up a second time, which was not fair, it spread itself about in a way which is not possible with a boiled egg."

Note on the Effect of Lightning on a Dwelling-House at Twickenham, September 23rd, 1890.

By A. BREWIN, F.R.Met.Soc.

[Received December 2nd.—Read December 17th, 1890.]

ON the 23rd of September, 1890, my house at Strawberry Hill Road, Twickenham, was struck by lightning, and it may be of some interest if I briefly state what took place. The storm, which lasted a very short time and was accompanied by torrents of rain, came on about 4 p.m., and at 4.15 the house was struck, the flash being accompanied by a heavy crash of thunder.

The house is in a row of detached houses, of the modern Queen Anne's Villa style, all of the same elevation, and there are no tall trees within 150 yards. It is built with double rooms, the two rooms on the ground floor opening into each other with folding doors, which were open. The fireplaces of these rooms are against the outside wall, one above the other, so that there are two stacks of three chimneys each.

The stack to the chimneys of the front rooms was cleft down the outside for some feet, many bricks thrown down to the ground, and the roof broken in two places by the flash, which a neighbour, who was looking out of window at the time, said seemed to separate and strike in several places. Internally

the middle (first floor) room of this front set was the only one affected; everything was knocked off the mantel-piece—an iron one—, but nothing broken; a spring clock knocked flat on its face was picked up going and apparently uninjured. The room was filled with a stifling sulphurous vapour. Two children were in it, and when the servant ran in, the little boy of 6 said his head had been knocked, and the girl of 10 said she “felt all over prickles,” a not unnatural feeling if one receives an electric shock. I should mention that, owing to the rain, all the windows were shut, excepting in the back ground floor room. Mrs. Brewin was sitting with two friends in the front ground floor room, and that room was uninjured, though it was below the room, before described, where the children were.

The stack to the chimneys of the back rooms was uninjured, but a rain-water pipe running outside had a piece cut out on a line with the fireplace of the middle (first floor) room. In this room, the tiles of the hearth were lifted, and the carpet near them pushed up, and a heavy china slop pail and water jug standing near the fireplace were knocked together and slightly chipped; there were no marks on the flooring, but there was a hole of about 18 inches diameter made in the ceiling of the room below. At first I thought this was all caused by the concussion on the pipe outside being struck, as no lightning was seen passing out of the back room windows by those sitting in the front; but on taking up the boards there was conclusive evidence that the lightning had entered, as the wires to the electric bells were cut, fused in several places, and the insulating material stripped off them for several feet, and either burnt or pushed back into a heap. All the vases and ornaments on the mantel-piece in the back ground floor room were upset and knocked over, but none broken. The ceiling was found to be so much damaged that it had all to come down.

It is to be presumed that on this, the back side of the house, the lightning came down the chimney of the middle room, passed at the back of the fireplace underneath the tiles, and then through the ceiling, fusing the wires on its way, and out through the open window; but still the water pipe being broken is unaccounted for, as there was certainly no communication through the wall between it and the fireplace. The lightning took no effect on either of the top rooms.

DISCUSSION.

Mr. BLANFORD drew attention to the fact that the occurrence described by Mr. Scott took place on January 5th, whereas he did not visit the place until October, so that there had been ample time for a certain amount of myth to have become incorporated in the relation of some of the incidents.

Mr. SYMONS said that the story of the eggs narrated by Mr. Scott, reminded him of the fact that the inside skin, which separated the shell of an egg from the white, possessed a very good meteorological reputation, it having been used years ago for hygrometrical purposes. With the exception of the damage to the basket of eggs, there appeared to be nothing extraordinary in the action of the lightning as described in either Mr. Scott's or Mr. Brewin's paper. The hole knocked in the wall opposite the spot where the crowbar was standing, and the upsetting of articles on the mantel-shelf, were quite ordinary occurrences. These cases of damage served to show the necessity of houses being protected by

lightning conductors. Bells were almost always affected when a building was struck by lightning. As regarded the breaking of the rain-water pipe outside Mr. Brewin's house, it was just possible that the damage might have been done some time previously by the action of frost or otherwise, but remained undiscovered until the thorough examination of premises was made after they were struck by lightning. Rain-water pipes, provided the joints were good, acted as efficient lightning conductors.

Mr. BREWIN said that the piece knocked out of the rain-water pipe was just above a joint.

Mr. WILSON said he understood Mr. Scott to say that the damage to the eggs was due to an explosion in the basket. He would like to know what there was in an egg which was likely to explode. He related a case of a lightning flash in Natal which struck a farm house, when near a powder flask was a pile of new cotton shirts on a shelf. A clean round hole was drilled through the whole parcel of shirts, without any further damage.

Mr. SCOTT said that as there was sufficient electrical discharge to disturb the fire-grate and injure the floor, it was possible that the vibration might have caused the damage to the eggs.

Mr. WHIPPLE suggested that Mr. Brewin should obtain an actual measurement of the electric force necessary to produce such effects as were seen on the bell-wires shown to the meeting. It would also be interesting to ascertain the amount of electrical force necessary to blow a hole in a rain-water pipe.

Mr. TRIPP remarked that there might have been moisture in the rain-water pipe, and if so, the heat of the flash may have given rise to a sudden generation of steam resulting in an explosion and thus damaging the pipe.

Mr. MARRIOTT said that the two storms described in these papers were interesting, as one was a winter storm and the other a summer storm. He had looked at the Weather Chart for January 5th, and found that there was a strong gale blowing at Belmullet, the wind being force 10, and the barometer below 29 inches. The thunderstorm on that day was no doubt due to the passage of a small satellite of the main depression. It was not uncommon to have a thunderstorm occurring to the south or south-east of great depressions.

WIND SYSTEMS AND TRADE ROUTES BETWEEN THE CAPE OF GOOD HOPE AND AUSTRALIA.

By Capt. M. W. CAMPBELL HEPWORTH, F.R.Met.Soc., F.R.A.S.

(Plate V.)

[Received October 15th.—Read December 17th, 1890.]

THE trade with Australia carried on by sailing vessels is still considerable, and although most of the steam shipping in the Australian trade proceeds to Australia by way of the Suez Canal, there are nevertheless a large number of steamships which take the route *via* the Cape of Good Hope. As it is yet a subject for debate as to which is the best parallel for running down the easting between Cape Point, or the meridian of Cape Point, and that of Cape Leeuwin, it would doubtless be in a good cause were modern meteorologists to take up the subject, and by seeking data and inviting discussion, endeavour to arrive at the truth.

In recommending the parallel of 39° S in preference to a higher latitude, that most valuable work, *The Australia Directory*, compiled by Captain C. B. Yule, R.N., and published by order of the Lords Commissioners of the Admiralty, gives the following in a foot note :—

"Although the parallel here assigned of 39° S. as being that where ships may safely run down their longitude, has been objected to by some writers on the ground that of late years many successful passages have been made in much higher latitudes, some even attaining the 55^{th} parallel for the southern point of their great circle or composite route, still it has been deemed desirable to retain the directions given in former editions of this work, placing before the navigator the grounds for this decision."

"It is true that the distance from the meridian of the Cape of Good Hope to Bar's Strait, or the south coast of Tasmania, is diminished greatly as every succeeding higher parallel of latitude is adopted. For example, the 40^{th} parallel has an advantage over the 38^{th} parallel of 880 miles, or nearly two days' sailing; and again the 45^{th} parallel has an advantage over the 40^{th} to the extent of 650 miles; the 50^{th} over the 45^{th} of 480; and so far, the higher the latitude of the great circle or composite route adopted, the more advantageous is the route in point of distance. But the disadvantages attending the selection of any high parallel should be clearly understood by the seaman, and more especially as regards a passenger ship, or small or ill-found vessel, or one deeply laden."

"Maury, in advocating the higher parallels of latitude, says:—'In recommending this route, which differs so widely from the favourite route of the Admiralty, I do it, not because it is an approach to the great circle route, but because the winds and sea and the distance are all such as to make this route the quickest;' and again, 'The winds to the north of the 40^{th} parallel of south latitude are much less favourable for Australia than they are to the south of that parallel.'"

"The evidence in favour of these opinions as to the winds and seas being more favourable south of 40° appears, however, by no means conclusive; many experienced navigators are of opinion that north of 40° the steadiness and comparative moderate strength of the winds, combined with the smoother seas and more genial climate, compensate by comfort and security the time presumed to be saved by the shorter route made in the tempestuous gales, the sudden, violent, and fitful shifts of wind, accompanied with hail and snow, and the terrific irregular seas which have been frequently encountered in the higher latitudes adopted."

"Independently of the extreme severity of the climate occasionally experienced in high latitudes, there exists the lurking danger of disrupted masses of ice, and icebergs of larger dimensions. The absence of approximate positions of these dangers cannot be depended on for any season of the year; they are, however, rarely encountered north of 40° south, except in the vicinity of the Cape of Good Hope. Between 40° and 45° south, they have been occasionally fallen in with, extending as far as the 65^{th} meridian of E longitude; on the 45^{th} parallel as far as 135° E; and on the 50^{th} parallel extending to 140° E."

I have given the quotation at length because of importance in showing what a wide divergence of opinion existed upon this question between two such eminent authorities; a divergence of opinion which exists at the present time amongst the navigators of the South Indian Ocean.

It is with the object of raising discussion upon this subject that I now bring this paper before the Royal Meteorological Society, and although the data I have collected with a view of arriving at some conclusion upon the subject at issue is of course far too limited for such pretensions, yet I venture to hope they may advance some proofs in favour of the routes usually adopted by me, and which I now presume to recommend. I say "routes" advisedly, because to the parallel adopted in summer with advantage, it might during winter months be inadvisable to adhere.

Through the kindness of Messrs. Wm. Milburn and Co., I have had access to the log books of many of the steamers of the Anglo-Australasian Line, on voyages to Australia *via* the Cape of Good Hope, of which, in addition to those voyages I have myself made between the Cape and Australia, I now submit a brief abstract, dealing of course with those portions only which appertain to this subject.

In this abstract and the accompanying diagram which has been drafted by me for this purpose, there is roughly given the direction and force of the wind; when necessary, the direction and disturbance of the sea, and the state of the weather experienced in the latitude of each succeeding interval of ten degrees of longitude between the 20th and 140th meridians of east longitude, in a line devoted respectively to each steamer whose log has been summarised. These log books have not been selected; those which are not of my own voyages have been taken haphazard from amongst a large collection.

In most cases the recorded force of the wind will probably be underestimated; as when a vessel is running at a high rate of speed before the wind, the observer is apt to undervalue it, not taking sufficiently into consideration the modifying effects resulting from the onward progress of the ship. The direction of the wind also, as given, is doubtless subject to some error, arising from the aberration caused by the onward progress of the vessel. The disturbance of the sea may in some cases be exaggerated or under-estimated, according to the trim of the vessel on which the observation was recorded, and *ergo*, her behaviour in a scaway. Absolute accuracy therefore is not claimed for these abstracts.

My own experience and information, gleaned in conversation with other commanders of vessels navigating the South Indian Ocean between the Cape and the Australian Colonies, led me some years ago to the belief that the best parallel on which to run down the longitude would be between the 41st and 42nd parallels during winter months, and between the 45th and 46th parallels during summer months. Additional observation, and the perusal of the log books of steamers proceeding between the Cape and Australia, have considerably strengthened this belief.

It is well known that the steady flow of Westerly winds in the South Indian Ocean is interrupted, occasionally during summer months, and frequently during winter months, by gales of cyclonic or semi-cyclonic origin.

The centres of these atmospheric disturbances appear to travel to the eastward, usually—east of the 80th meridian—on paths south of the 48rd parallel during the winter months, and south of the 46th parallel during summer months. Such being the case, in order to keep on the left hand, or westerly side, the most favourable route for vessels coming within their influence would appear to be somewhat to the northward of the 42nd parallel in the former, and somewhat to the northward of the 46th parallel in the latter months; the navigator, by taking this route, would thus make the utmost use of these strong fair gales, whereas by adopting the more southern route, there would be a probability of approaching the centre of the depression, or experiencing the adverse winds on the right of its centre.

These systems of low atmospheric pressure frequently travel to the eastward, for days, at so low a rate of speed that a full powered steamer running on the left-hand side of these centres will often keep up with them for hundreds of miles, sometimes overtake them, and not unfrequently leave them astern. In July, 1887, the s.s. *Port Pirie* ran on the left front of such a system for upwards of 1,200 Admiralty knots, or nearly 1,400 statute miles, and would in all probability have continued under its influence for hundreds of miles more, had she continued her onward progress; but having been stopped and hove-to under canvas in order to effect some repair to machinery, the trough of the depression within three hours passed the ship; the wind, during a hard squall of wind and rain, flying to the West-south-west, and afterwards veering still more to the Southward. The *Port Pirie* had been making about 800 Admiralty knots per day, while in company with this system. This instance is cited, because the position of the ship relative to the centre of the disturbance could be localised from time to time by the appearance of the sky, the veering and backing of the wind, and the oscillations of the mercury.

In May, 1888, the s.s. *Port Victor* encountered a low level cyclone in lat. 88° S., long. 25° E., which she evidently overtook when running to the south-eastward. She appears to have crossed the centre, and was then hove to; when the cyclone passed to the south-eastward. The wind having moderated, continuing her course to the south-east, the vessel again overtook the system, and running to a position north-eastward of its centre, or on its left front, was again hove to, this time for twenty-four hours.

In January, 1889, the s.s. *Port Pirie* overtook a cyclonic disturbance travelling to the east-south-east in lat. $45^{\circ} 30'$ S., long. $44^{\circ} 2'$ E, and appears to have fallen in with the steep gradients in rear of its centre. With the wind at South-west, she ran to the north-eastward, and would doubtless soon have run out of the sphere of its influence, but encountering the inevitable westerly sea, she had to be hove-to, in order safely to combat the dangerous cross sea.

Yet another instance may be cited here. In July, 1890, the s.s. *Port Adelaide* encountered a cyclone. She first came under its influence in lat. 87° S., long. 17° E., when steering to the south-eastward. The Westerly wind which had been experienced since the trades were lost in 26° S. had died away, and a breeze had sprung up fresh from south-east with falling mercury. Skirting the system on the edge of its right side, the vessel crossed its right front, the wind veering through East to North, and increasing rapidly.

The cyclone which up to this time would appear to have remained almost stationary, now gained on the vessel, and the wind at North-west blew a strong gale in lat. $89^{\circ} 30'$ S., long. 22° E.

From this position to the meridian of 86° E. in the same parallel, a strong to whole gale was experienced veering and backing between West-north-west and West-south-west, according as the disturbance gained or lost on the position of the steamer. The wind then backed to North-west, and

freshened with a fast falling barometer, and very ugly appearance; the sea rapidly increasing. The vessel was hove to, *i.e.* brought with her head to the sea, the engines going dead slow. For about an hour after noon—the vessel having been hove-to at 6 a.m.—the wind was moderate, the mercury still falling. Then a furious gale with squalls of hurricane force, accompanied with a tremendous sea was experienced for fourteen hours, the wind veering gradually to South-west, at which point it commenced to moderate.

Many vessels which, in winter, have proceeded to the eastward south of the 42° parallel, have experienced some Easterly winds, presumably from having been on the right side of the centre of areas of low pressure; at any rate there is strong evidence for the supposition that the lower the latitude the less chance there will be of encountering an Easterly wind. North of the 42nd parallel an Easterly wind has not been met with, in my experience, between the 80th and 120th meridian of East longitude.

The winds on the right hand side of the depression which traverse the Southern Ocean are found usually to be moderate; the gradients, it may be presumed, being slight, owing to the permanent low pressure lying to the southward. However, the *s.s. Port Pirie* in the month of June, 1889, in latitude 48° S. and longitude 85° E., encountered a very heavy gale from the North-east, there being every indication that she was at the time on the right front of a cyclonic system.

Although it is probable that the force of the wind, in most cases, will not be found to be greater near the centres of these systems, a near approach to them is to be avoided; for instead of the steady gale and even sea experienced well to the northward of them, a dangerous cross, or confused, sea would be encountered, and in consequence of the greater incurvation of the wind near the centre on the left front, its direction would be North, or even North-north-east, instead of North-north-west or North-west, on their approach, and the shifts of wind would be very sudden.

The synopsis deduced from the survey of the log books which I have summarised tends towards proof of the exemption from Easterly winds, and the comparative moderate strength of the gales north of the 40th parallel.

According to the newspaper report, the *s.s. Damascus* in August 1890, experienced Easterly winds from the Cape of Good Hope to the meridian of Cape Leeuwin, the 44th parallel being adopted for running down the longitude.

In July 1886, the *s.s. Port Pirie*, running down the easting in the 89th parallel, experienced nothing but Westerly wind, while the *s.s. Port Phillip* in the 48rd parallel was encountering a succession of Easterly winds at the same time.

My abstract shows that during the months of April, May, June, July and August, in the parallel of 42° S., and north of this parallel, three Easterly winds have been experienced in six voyages; south of this parallel nineteen Easterly winds in seven voyages; that during the months of January, February and March, in the 44th parallel, and north of this parallel six Easterly winds were experienced in three voyages; south of this parallel three in two voyages. The Easterly winds thus noted have lasted from twelve to forty-eight hours.

Month.	Steamers.	Highest Lat. S.	Gales.		No. of Easterly Winds between 20°-120° E.
			Force 8 to 10.	Force above 10.	
January	1887.... Port Pirie	46	2	0	0
"	1888.... Hankow	39	0	0	0
"	1889.... Port Pirie ..	45½	0	1	3
February	1887.... Port Pirie	44	0	0	1
March	1888.... Port Darwin.....	41	2	0	3
April	1888.... Port Denison	45	1	0	0
May	1887.... Port Adelaide	43	0	2	0
"	1887.... Port Jackson	44	3	0	7
"	1888.... Port Victor	42	1	2	0
"	1889.... Port Victor	44	1	0	4
June	1889.... Port Pirie	44	1	1	5
July	1886.... Port Pirie	39	3	1	0
"	1888.... Hankow	37	5	0	0
"	1889.... Port Darwin	42	2	0	2
"	1890.... Port Adelaide	42½	2	1	1
August	1887.... Port Pirie	41½	3	0	0
"	1888.... Port Phillip	45	3	0	2
"	1889.... Hankow	39	2	0	1

Should but a general idea of the usual track of the centre of these systems of low pressure be ascertained for each season of the year, such information would be invaluable to the navigator in the "roaring forties" of the Southern Ocean.

In fourteen voyages on which the easting was made in parallels south of 40° S., ice was once only met with; on many of these voyages the easting was made south of the 44th parallel.

DISCUSSION.

Mr. BLANFORD said that Capt. Hepworth's paper was of great interest. The storms noticed were, of course, not those tropical storms which formed the field of Mr. Meldrum's work, but appeared to be similar to those in the Northern Hemisphere which cross the Atlantic between the United States and the shores of Europe.

Mr. SCOTT said that he had been much interested in listening to Capt. Hepworth's paper, but thought that his experience of ice had been extremely fortunate. The July track recommended by Capt. Hepworth lay in 'blue water,' as shown on the Admiralty charts, where there was not much danger from ice, but the route recommended for January traversed that part of the ocean which the Admiralty charts showed was dangerous on account of floating ice. January was the month when the ice broke away from the South Pole, and came down into a lower latitude. He inquired if Capt. Hepworth knew how many ships belonging to the New Zealand Company had been reported as missing, probably owing to collision with ice, during the last five years.

Capt. HEPWORTH said he advocated the parallels of 45° and 46° as the best route, because in his experience ice had not been met with. Of course ice was more likely to be encountered in these latitudes than in a lower latitude, but the danger was very slight. He believed the ships of the New Zealand Company went much further south than 46°, and were therefore more likely to encounter ice.

Mr. BAYARD said he presumed that as the Antarctic regions were so much

colder, the ice did not break away so soon or to so great a degree as in the Arctic regions.

Capt. HEPWORTH remarked that he recommended a higher southern latitude for the summer months on account of the more favourable winds and weather. He had not taken the question of ice into consideration, as he had never encountered any.

Capt. WILSON-BARKER said that he had been in the region referred to by Capt. Hepworth, and had generally run down the longitude at about the 42nd parallel. He had never seen ice. The question of the best trade route between the Cape of Good Hope and Australia was very important, but he thought it was a matter which could not be satisfactorily settled without studying the areas of barometric pressure outside the district traversed.

Lieut. W. F. CABORNE, R.N.R. (on being called upon by the Chairman), said that, having arrived late, he had not had the advantage of hearing the paper read, and, therefore, was not in a position to make any remarks upon it calculated to be of interest or value to the Society; however, he had had a certain amount of experience in the region under discussion some years ago, and had never encountered ice between the Cape of Good Hope and the meridian of Melbourne, although he had upon one or two occasions travelled along a rather southerly route.

Capt. MACLEAR wrote to say that he could not be present at the reading of the paper, but having studied it and the diagrams, he considered that it confirmed the Admiralty sailing directions in recommending the parallel of 39° to 40° S. as desirable generally for ships to run down their longitude.

REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1890.

By EDWARD MAWLEY, F.R.MET.SOC., F.R.H.S.

[Read December 17th 1890.]

ALL the observers in 1889 have again sent in returns this year. The observations from Usk were, however, not sufficiently numerous to allow of their tabulation. Returns have also been received from Mrs. Green, Cloughton, Caton, Lancashire, and from Mr. J. Hopkinson, the Grange, St. Albans, Hertfordshire.

In order to test the relative accuracy of these returns, I have drawn curves to represent the dates of first flowering of the fourteen plants whose names are printed in bolder type on the list. These curves, when compared with those drawn for the previous year, come out in nearly every case somewhat smoother. From this it may reasonably be inferred that the observations have, as a rule, been made during the past twelvemonth with greater care. This I am very pleased indeed to find. Nevertheless there still occur here and there discrepancies in the records which are very difficult to understand. I will, however, say no more on this point, for with such a small number of returns, it is almost impossible to pick out with any certainty, from among the trustworthy observations, those which have not been made in accordance with the instructions issued by the Society.

LIST OF OBSERVERS.

District.	Station.	County.	Observer.
A.	Babbacombe (Torquay)	Devon	E. E. Glyde
"	Tiverton	Devon	Miss M. E. Gill
"	Westward Ho (Bideford)	Devon	H. A. Evans
"	Wells	Somerset	The Misses Livett
B.	Killarney	Co. Kerry	Ven. Archdeacon Wynne, M. A.
"	Wicklow	Co. Wicklow	The Misses Wynne
C.	Pennington (Lymington)	Hants	Miss E. S. Lomer
"	Buckhorn Weston (Wincanton)	Dorset	Miss H. K. H. D'Aeth
"	Salisbury	Wilts	W. Hussey and E. J. Tatum
"	Swanley (Dartford)	Kent	C. H. Hooper
"	Ealing	Middlesex	A. Belt
D.	St. Albans	Herts	J. Hopkinson
"	Oxford	Oxford	F. A. Bellamy
"	Northampton	Northampton	H. N. Dixon
"	Thurcaston (Leicester)	Leicester	Rev. T. A. Preston, M. A.
"	Belton (Grantham)	Lincoln	Miss F. H. Woolward
"	Macclesfield	Cheshire	J. Dale
"	Hodsock (Worksop)	Nottingham	Miss A. Mellish
E.	Tacolneston (Wymondham)	Norfolk	Miss E. J. Barrow
F.	Settle	{ Yorkshire	S. S. Burlingham and
"	Claughton (Caton)	{ (West Riding)	The Misses Thompson
H.	Tynron	Lancashire	Mrs. E. J. Green
I.	Durham	Dumfries	J. Shaw
		Durham	H. J. Carpenter

The Autumn of 1889.

During the first half of September the weather was dry and quite summer-like in temperature, thus allowing the harvest to be completed under exceptionally favourable conditions. After this time until the end of October there seldom occurred either a warm or dry day. November proved on the whole very mild, but towards its close there were several keen frosts which gave vegetation its first decided check. Both wild and garden flowers were unusually plentiful, but suffered a good deal from the rains of October and the frequent fogs and humid atmosphere of the last month of the season. Owing to the same causes and the deficiency of clear sunshine, the wood of fruit and other trees had become only moderately ripened by the end of the autumn. The autumnal tints are reported by several observers to have been unusually fine. During November the weather in the West of Scotland was more unseasonably mild than in any of the other districts.

Observers' Notes.

SEPTEMBER 1889.—*Babbacombe* (A.). Streams low. *Salisbury* (C.). 17th. Dahlias killed in a nursery garden near the river. *Hodsock* (D.). Trees began to change colour suddenly quite at the end of the month. *Claughton* (F.). 21st to 23rd. A very sharp and early frost destroyed all the dahlias and tender garden plants.

OCTOBER.—*Babbacombe* (A.). Sycamore defoliated. *Pennington* (C.). The lime and ash had lost all their leaves by the end of the month. Autumnal tints very fine. 23rd. Large flocks of green plover seen. *Claughton* (F.). 7th. A severe storm brought down a great many leaves from the trees. 18th. The woods still very lovely with their varied tints. Hips very plentiful, haws less so.

NOVEMBER.—*Babbacombe* (A.). Autumnal tints very fine in early part of month. Trees defoliated as follows. 1st. Horse chestnut. 5th. Wych elm. 11th. Common poplar. 22nd. Elm. 25th. Beech and all other deciduous trees. *Pennington* (C.). Birds singing up to 26th.

The Winter of 1889-90.

The first winter month was changeable in temperature, but on the whole rather cold. There occurred but little rain, and the duration of bright sunshine was small even for December. In the West of Scotland, however, the weather still continued remarkably mild, primroses and wall-flowers remaining in flower in sheltered places throughout the month. January proved exceedingly mild, the night temperatures especially being everywhere singularly high. Although rain fell at frequent intervals and in excess of the average, there was a satisfactory record of sunshine. Many wild flowers were here and there to be found, and vegetation generally was very forward for mid-winter. The average date of the first flowering of the hazel, taking all the stations, was January 15th, which, for the same stations, is a month earlier than in the previous year. February, in complete contrast to January, was more like a typical March, being cold, dry and sunny, with a great prevalence of Easterly winds. This was a splendid month for working the land, and kept the wheat and other crops well in check. In fact all vegetable growths may be said to have remained throughout it more or less at a standstill. The scarcity of Holly berries was one very noticeable feature of this winter.

Observers' Notes.

DECEMBER 1889.—*Babbacombe* (A.). Many flowers in bloom. *Pennington* (C.). Primroses used for Church decorations. Holly berries scarcely to be found anywhere. *Cloughton* (F.). Total absence of Holly berries.

JANUARY 1890.—*Babbacombe* (A.). Vegetation forward, many flowers in bloom, and birds singing throughout the month. Nasturtiums still green. *Pennington* (C.). Several of the forest trees budding and honeysuckle in leaf. *Buckhorn Weston* (C.). The grass has already begun to grow, and here and there the hedges are bursting. *Ealing* (C.). 26th. Saw a *Rhododendron* in flower in Kew Gardens. *Thurcaston* (D.). A very forward month. 8th. Aconites in flower. *Hodsock* (D.). Hazel and Snowdrop earlier than in any year since I began observing in 1883. *Tacolneston* (E.). Song of lark, robin, and both song- and missel-thrushes frequent. Great tit heard.

FEBRUARY.—*Usk* (N.). 18th. Noticed sandpipers about the river here for the first time. *Wells* (A.). Vegetation very forward at end of month. *Pennington* (C.). Birds active and full of song at the beginning of the month, but more quiet as the colder weather came on. 28th. Peach and Nectarine in blossom. *Ealing* (C.). Found Hazel and Coltsfoot earlier than I ever remember. *Northampton* (D.). Extremely unfavourable to the progress of vegetation. 22nd. A *Daphn Mezereum* in full blossom. *Thurcaston* (D.). Everything at a standstill, I do not remember all plants so long stationary. *Tacolneston* (F.). During the last fortnight all growth stopped by cold winds.

The Spring of 1890.

At the beginning of March there occurred a series of frosts of very exceptional severity. Over a great part of England lower temperatures were then recorded than at any time during the preceding winter months. As shown by Mr. C. Harding in his paper¹ "On the Cold Period at the beginning of March

¹ *Quarterly Journal*, Vol. XVI. p. 152.

TABLE I.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1890.

Name of Plant.	A. England, SW.			B. Ireland, S.		C. England, S.				D. England, Midlands.						F. England, NW.		H. W.		I. NE.			
	Babacombe.	Tiverton.	Westward Ho.	Wells.	Killarney.	Wicklow.	Pennington.	Buckhorn Weston.	Salisbury.	Swanley.	Balling.	St. Albans.	Oxford.	Northamp- ton.	Thurleston.	Belton.	Macclesfield.	Hodsock.	Tadcolneston.	Settle.	Cloughton.	Tyron.	Darham.
1. <i>Corylus Avellana</i>	10	..	..	..	10	14	7	30	10	10	10	..	..	14	20	15	36	4	11	9	..	41	35
2. <i>RANUNCULUS FICARIA</i>	65	27	61	44	11	29	32	11	15	41	..	56	50	71	39	41	75	54	19	74	76	..	70
3. <i>Mercurialis perennis</i>	69	27	63	42	..	..	56	29	16	84	..	67	52	74	82	..	..	54	41	85	29	..	..
4. <i>TUSILAGO FARFARA</i>	70	51	54	50	53	53	58	50	18	49	..	..	43	53	43	41	44	..	59	8	90	75	64
5. <i>Narcissus Pseudo-narcissus</i> .....	..	55	..	..	36	40	58	..	85	..	71	76	..	85	82	..	74	71	75	..	76	..	..
6. <i>CALTHA PALUSTRIS</i>	79	78	82	72	70	98	85	36	81	..	..	103	86	76	89	94	86	93	75	..	93	116	122
7. <i>Salix caprea</i>	69	31	..	65	..	54	33	77	20	74	..	67	76	66	74	..	75	..	72	85	..	..	77
8. <i>ANEMONE NEMOROSA</i> .....	..	81	82	56	41	76	85	87	57	82	..	79	84	..	80	..	81	85	90	91	90	93	115
9. <i>Nepeta Glechoma</i>	79	56	68	79	50	68	90	76	81	41	..	94	85	88	91	97	109	98	86	117	120	110	89
10. <i>PRUNUS SPINOSA</i>	76	83	85	86	29	40	94	92	73	76	..	103	92	82	97	..	105	91	98	88	93	96	104
11. <i>PRIMULA VERIS</i>	88	..	..	88	98	88	110	83	87	..	..	92	..	109	94	102	120	98	80	81	..	..	121
12. <i>Cardamine pratensis</i>	114	86	96	80	..	..	85	..	87	..	116	..	..	110	104	..	126	110	..	..	..	..	123
13. <i>Stellaria Holotea</i>	91	87	90	100	52	95	73	109	92	..	120	104	112	117	116	132	120	108	90	128	121	119	96
14. <i>SCILLA NUTANS</i>	101	97	118	86	93	106	101	94	87	..	110	104	109	109	104	112	120	108	120	..	109	121	99
15. <i>Ranunculus acris</i>	122	116	126	..	130	130	124	109	110	..	119	..	99	134	126	123	138	135	..	139	130	127	..
16. <i>Veronica Chamaedrys</i>	91	90	90	..	101	106	91	79	85	49	..	109	117	117	124	123	128	119	..	138	127	..	133
17. <i>Plantago lanceolata</i>	104	116	98	..	102	81	106	113	94	..	122	117	115	129	117	161	131	117	..	127	..	122	133
18. <i>Sisymbrium Officinalis</i> .....	..	111	109	..	110	116	113	100	101	..	120	..	92	109	115	123	129	107	105	127	125	..	..
19. <i>Vicia sepium</i>	138	74	..	113	94	75	134	113	102	..	..	136	..	127	..	134	136	125	127	144	..	..	..
20. <i>Ajuga reptans</i>	127	119	130	106	..	..	118	106	122	..	..	..	..	134	127	127	133	124	122	141	123	130	133
21. <i>GERANIUM ROBERTIANUM</i>	102	..	114	91	96	115	119	123	112	..	..	121	122	134	117	134	131	132	122	130	131	133	144
22. <i>Springa vulgaris</i>	120	..	121	119	110	108	116	126	119	..	120	126	122	128	132	132	137	127	..	138	..	133	142
23. <i>Æsculus Hippocastaneum</i>	120	..	..	122	110	98	121	122	121	..	124	127	123	128	132	139	137	123	154	138	..	126	141
24. <i>Galium Aparine</i>	127	140	..	..	156	155	128	142	115	..	..	136	134	146	130	..	141	..	..	141	..	..	..
25. <i>Crataegus Oxyacantha</i>	122	..	126	115	112	129	133	122	..	..	131	131	126	129	133	124	142	126	134	138	..	145	140
26. <i>Cytisus Laburnum</i>	122	..	127	111	125	125	134	124	..	..	130	128	135	136	132	139	134	137	134	137	134	..	140
27. <i>Potentilla anserina</i>	139	140	125	..	134	125	135	134	124	..	..	136	148	139	152	144	153	144	153	142	142	..	169
28. <i>Lotus corniculatus</i>	142	..	130	..	112	108	135	129	124	..	..	139	147	149	135	151	145	144	143	144	..	..	148
29. <i>Hieracium Piloella</i>	142	140	137	..	..	132	..	146	127	..	..	..	..	147	108	141	155	144	134	144	..	148	..

TABLE I.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1890.—Continued.

Name of Plant.	A. England, SW.			B. Ireland, S.		C. England, S.				D. England, Midlands.					England, E.	England, NW.	Scotland, W.	England, NE.					
	Babbacombe.	Tiverton.	Westward Ho.	Wells.	Killarney.	Wicklow.	Pennington.	Buckhorn Weston.	Salisbury.	Swanley.	Ealing.	St. Albans.	Oxford.	Northampton.	Thurcaston.	Belton.	Macclesfield.	Hodsock.	Tacolneston.	Settle.	Claghon.	Tyrum.	Durham.
30. TRIFOLIUM REPENS	143	..	149	..	147	114	143	146	142	..	..	..	..	148	142	152	162	135	138	172	..	169	..
31. Chrysanthemum Leucanthemum ..	142	151	149	135	146	128	137	135	128	..	125	139	140	149	151	149	155	144	145	169	..	161	180
32. Lysichitis Flos-cuculi	143	147	141	..	149	..	144	142	145	..	..	..	136	149	152	..	..	154	145	..	..	167	..
33. Lathyrus pratensis	158	..	155	..	..	146	157	152	143	..	..	..	174	170	158	..	162	164	149	..	..	165	..
34. Iris pseud-acorus	152	137	137	..	131	148	141	149	..	..	..	152	149	169	..	153	161	158	..	167	..	166	177
35. Rosa canina	158	137	150	..	151	152	155	150	144	..	152	152	161	157	159	171	157	152	152	182	..	180	..
36. ACHILLEA MILLEFOLIUM	178	168	172	172	172	172	172	149	167	..	..	173	185	173	166	181	173	175	182	182	..	185	..
37. MALVA SYLVESTRIS	163	155	..	..	..	151	150	164	160	..	181	166	160	161	163	..	164	170	..	184	195	..	
38. Stachys sylvatica .....	..	155	..	..	159	157	157	158	..	..	..	..	175	173	177	173	173	176	..	181	..	178	180
39. Spiraea Ulmaria	170	..	..	..	172	168	182	..	173	..	..	..	160	170	166	..	170	168	..	183	..	185	..
40. Prunella vulgaris	163	175	..	..	152	148	152	154	172	..	..	..	174	161	170	170	179	159	..	198	..	..	..
41. Liguatrum vulgare	165	179	163	..	157	161	..	163	..	..	..	..	175	170	168	..	173	184	180	191	..	184	..
42. Vicia Cracca	167	177	..	..	176	162	167	155	171	..	..	..	175	170	168	..	173	184	..	198	..	184	..
43. Senecio Jacobaea	191	167	191	..	173	188	211	189	..	..	..	..	171	196	..	188	183	185	183	194	..	194	..
44. CENTAUREA NIGRA	172	182	..	..	182	168	171	184	..	..	173	173	170	175	..	186	174	..	183	195	198	..	
45. Galium verum	179	180	..	..	175	195	169	176	..	..	..	..	170	175	181	187	180	185	195	195	180	..	
46. Carduus arvensis	178	179	..	..	..	182	..	182	..	..	..	188	186	183	..	188	182	185	210	197	197	..	
47. CAMPANULA ROTUNDIFOLIA .....	..	..	..	..	..	174	..	200	..	..	..	188	186	183	..	188	197	188	188	188	195	188	
48. Galeopsis Tetralix .....	..	..	..	..	..	191	..	208	..	..	..	..	..	186	..	192	192	192	191	191	..	..
49. CONVULVULUS SEPNUM	202	..	174	..	191	..	187	208	..	..	269	..	..	263	..	187	192	174	192	192	..	..
50. Hedera Helix	166	..	254	254	266	272	..	..	..	..	..	..	..	..	..	..	281	260	..	..	..	..

English Names of above Plants.—1. Hazel. 2. Lesser Celandine. 3. Dog's Mercury. 4. Coltsfoot. 5. Daffodil. 6. Marsh Marigold. 7. Great Sallow. 8. Wood Anemone. 9. Ground Ivy. 10. Black-thorn. 11. Cowslip. 12. Cuckoo Flower. 13. Greater Stitchwort. 14. Blue-bell. 15. Upright Crowfoot. 16. Germaner Speedwell. 17. Ribwort Plantain. 18. Garlic Hedge Mustard. 19. Bush Vetch. 20. Bugle. 21. Herb Robert. 22. Lillac. 23. Horse Chestnut. 24. Cleavers. 25. Hawthorn. 26. Laburnum. 27. Silver-weed. 28. Bird's Foot Trefoil. 29. Mouse-ear Hawkweed. 30. Dutch Clover. 31. White Ox-eye Daisy. 32. Ragged Robin. 33. Meadow Vetching. 34. Yellow Iris. 35. Dog Rose. 36. Milfoil. 37. Common Mallow. 38. Hedge Woundwort. 39. Meadow-sweet. 40. Soft-heal. 41. Privet. 42. Tufted Vetch. 43. Ragwort. 44. Black Knap-weed. 45. Yellow Bedstraw. 46. Field Thistle. 47. Harebell. 48. Hempenettle. 49. Greater Bind-weed. 50. Ivy.

During January vegetation was everywhere remarkably forward. Throughout the next two months Wild Flowers were as a rule only moderately early, but from this time until the middle of June they were very early in making their appearance. During the rest of the Summer, and especially in July, their blossoming was greatly retarded.

TABLE II.—DATE (DAY OF YEAR) OF FIRST SONG AND MIGRATION OF BIRDS, 1890.

District.	Stations.	SONG.							MIGRATION.						
		Song Thrush.	Nightingale.	Willow Wren.	Chiff-chaff.	Skylark.	Cuckoo.	Turtle Dove.	Flycatcher.	Swallow.	House Martin.	Sand Martin.	Swift.	Goatsucker.	Corncrake.
A.	Babbacombe .....	..	..	..	..	112	95	..	104	..	..	..	..	..	..
"	Westward Ho .....	..	..	..	93	120	..	..	93	..	..	127	..	..	..
B.	Killarney .....	..	..	..	..	126	..	..	97	..	..	..	..	..	124
"	Wicklow .....	..	..	..	88	54	89	..	103	..	141	127	..	..	115
C.	Pennington	7	110	..	90	32	106	..	143	104	..	127	129	126	..
"	Buckhorn Weston	11	..	..	..	48	106	..	..	104	..	121	..	..	..
"	Salisbury .....	..	..	..	..	70	106	..	..	106	116	108	115	..	136
"	Ealing	12	109	..	..	12	110	..	..	99	..	131	..	..	..
D.	St. Albans .....	..	110	..	..	19	..	..	..	..	..	..	..	..	..
"	Oxford .....	..	..	..	89	..	112	..	..	107	108	108	126	..	120
"	Northampton .....	..	..	..	..	..	..	..	..	109	..	..	..	..	..
"	Thurcaston .....	..	..	..	..	..	114	..	..	124	..	..	..	..	..
"	Belton .....	..	109	..	..	39	112	99	140	110	126	128	138	..	134
"	Macclesfield	36	..	88	..	43	116	..	..	130	130	133	142	..	130
"	Hodsock	15	114	..	111	34	111	123	145	104	132	126	129	..	118
E.	Tacolneston	15	..	..	..	15	112	..	..	106	..	..	..	..	..
F.	Cloughton	29	..	..	..	74	117	..	..	124	124	115	..	..	..
H.	Tynron .....	..	..	..	..	..	117	..	..	120	130	..	..	..	128
I.	Durham	45	..	115	..	34	121	..	..	117	..	115	132	..	125

TABLE III.—DATE (DAY OF YEAR) OF FIRST APPEARANCE OF INSECTS AND FROG SPAWN, 1890.

District.	Stations.	1. <i>Melolontha vulgaris</i> .							7. Frog Spawn.		Tadpoles.
		1.	2.	3.	4.	5.	6.	7.			
A.	Babbacombe .....	..	88	65	..	90	143	..	..	..	..
"	Westward Ho	138	..	119	..	..	116	165	..	..	..
B.	Killarney .....	..	..	..	101	..	..	..	49	..	..
"	Wicklow .....	..	52	114	120	94	..	136	65	..	..
C.	Pennington	131	..	103	105	93	127	176	32	118	..
"	Buckhorn Weston	133	10	125	..	107	125	..	..	..	..
"	Salisbury .....	..	34	84	..	85	..	..	41	89	..
"	Swanley .....	..	58	..	..	..	..	..	80	..	..
"	Ealing .....	..	33	..	134	102	..	..	72	..	..
D.	St. Albans .....	..	67	..	95	98	..	..	71	..	..
"	Oxford .....	..	45	..	..	89	117	..	77	99	..
"	Northampton .....	..	71	..	..	106	..	..	69	..	..
"	Thurcaston .....	..	..	..	..	119	138	175	..	..	..
"	Belton	140	12	..	122	116	139	..	..	..	..
"	Macclesfield .....	..	94	87	141	124	152	..	81	..	..
"	Hodsock	142	31	113	120	..	138	..	67	94	..
E.	Tacolneston .....	..	55	..	95	..	137	..	..	..	..
F.	Cloughton .....	..	120	..	..	129	..	..	..	..	..
I.	Durham .....	..	85	..	142	126	144	..	..	..	..

English Names of above Insects.—1. Cock Chafer. 2. Honey Bee. 3. Wasp. 4. Large Cabbage Butterfly. 5. Small Cabbage Butterfly. 6. Orange-tip Butterfly. 7. Meadow-brown Butterfly.

TABLE IV.—ESTIMATED YIELD OF FARM CROPS IN 1890.

Description of Crop.	England.					
	A. SW.	O. S.	D. Mid.	E. E.	F. NW.	I. NE.
Wheat	U. Av.	U. Av.	Av.	Av.	Av.	Av.
Barley	Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Oats	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Corn Harvest began,	225	220	223	222	231	233
average Date	(Aug. 13)	(Aug. 8)	(Aug. 11)	(Aug. 10)	(Aug. 19)	(Aug. 21)
Beans	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Peas	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	Av.
Potatoes	U. Av.	Av.	O. Av.	U. Av.	O. Av.	O. Av.
Turnips	O. Av.	O. Av.	O. Av.	Av.	O. Av.	O. Av.
Mangolds	O. Av.	Av.	O. Av.	Av.	O. Av.	O. Av.
Hay	U. Av.	U. Av.	U. Av.	U. Av.	Av.	O. Av.

Description of Crop.	Scotland.			Ireland.	British Isles.
	H. W.	J. E.	K. N.	B. and G. S & N.	
Wheat	U. Av.	Av.	..	Av.	Av.
Barley	Av.	O. Av.	..	O. Av.	O. Av.
Oats	O. Av.	O. Av.	U. Av.	O. Av.	O. Av.
Corn Harvest began,	247	251	261	240	235
average Date	(Sep. 4.)	(Sep. 8)	(Sep. 18)	(Aug. 28)	(Aug. 23)
Beans	Av.	O. Av.	..	..	O. Av.
Peas .....	..	..	..	..	O. Av.
Potatoes	U. Av.	U. Av.	Av.	U. Av.	U. Av.
Turnips	U. Av.	O. Av.	Av.	O. Av.	O. Av.
Mangolds .....	..	..	..	Av.	O. Av.
Hay	O. Av.	U. Av.	O. Av.	O. Av.	U. Av.

Symbols:—O. = Over. U. = Under. Av. = Average.

This Table has been compiled from Returns sent in to the *Agricultural Gazette* at the end of the Summer.

1890," these frosts were most severe on the South-eastern, Eastern and South Midland Counties. On the other hand, in the North of England and at the coast stations only moderate frosts prevailed. The areas within which serious injuries were done to shrubs, &c., appear, however, to have been very limited. These frosts necessarily gave a check to vegetation generally, for they lasted sufficiently long for the ground to become chilled to some depth. After the first week the weather remained fairly genial, so that in all districts March comes out as a rather warm month. The rainfall was about average, and there was comparatively little sunshine. The cold, dry and sunny weather of April proved very helpful to all farm and garden operations. Unfortunately, however, the frequent night frosts and cold winds proved very destructive to the blossoms of such hardy fruits as apples, pears and plums. May was another grand month for bringing all trees and plants gradually forward, and without serious check. Indeed, taking the Spring as a whole, it was an exceptionally favourable season.

TABLE V.—ESTIMATED YIELD OF FRUIT CROPS IN 1890.

Description of Crop.	England.					
	A. SW.	C. S.	D. Mid.	E. E.	F. NW.	I. NE.
Apples	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.
Pears	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.
Plums	Much	Much	Much	Much	Much	Much
Raspberries	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.
Currants	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	Av.
Gooseberries	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	Av.
Strawberries	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.

Description of Crop.	Scotland.			Ireland.	British Isles.
	H. W.	J. E.	K. N.	B. and G. S & N.	
Apples		U. Av.		U. Av.	U. Av.
Pears		U. Av.		U. Av.	U. Av.
Plums		U. Av.		U. Av.	Much
Raspberries		O. Av.		O. Av.	U. Av.
Currants		O. Av.		O. Av.	O. Av.
Gooseberries		O. Av.		O. Av.	O. Av.
Strawberries		O. Av.		O. Av.	O. Av.

Symbols:—O. = Over. U. = Under. Av. = Average.

This Table has been compiled from Returns sent in to the *Gardeners' Chronicle* and the *Garden* during the Autumn.

Observers' Notes.

MARCH.—*Babbacombe* (A.). Vegetation was much injured by the severe frosts in the beginning of the month. *Wicklow* (B.). Hawthorn and Horse chestnut were in many places out in leaf during the last week. *Pennington* (C.). Fruit trees in blossom much earlier than usual. Wild fowl very scarce all the season. *Buckhorn Weston* (C.). Although the first flowering is no earlier than usual, I think the general flowering is. *Salisbury* (C.). 26th. Leaves of Horse chestnut open. *Ealing* (C.). Vegetation, which had been at a standstill during the first half of the month, advanced very rapidly during the remaining fortnight. *Hodsock* (D.). Vegetation nearly a month earlier than usual. 10th. Apricot in blossom. 16th. Peach in blossom.

APRIL.—*Babbacombe* (A.). Vegetation forward at the end of month. 5th. Hazel and sycamore in leaf. 26th. Common poplar and Field elm in leaf. *Killarney* (B.). But few swallows seen up to end of month. *Pennington* (C.). At end of month everything looked unusually forward and green for the time of year. 8rd. Chestnut in leaf. 11th. Wryneck heard. *Buckhorn Weston* (C.). Foliage forward. *Salisbury* (C.). Fruit of elms very plentiful this year. 19th. Ash in flower. *Thurcaston* (D.). Very cold nights. *Hodsock* (D.). A few leaves out on beeches at end of month. *Tynron* (H.). There is an extraordinary promise of blossom, especially on the hawthorn.

MAY.—*Babbacombe* (A.). Vegetation was forward and the bloom on the flowering shrubs and trees luxuriant. Leafing as follows: 2nd, Beech and Wych Elm; 7th, Lime; 12th, Ash; and 14th, Oak. *Westward Ho* (A.). 15th. Oaks well out in leaf. *Wells* (A.). Vegetation progressed rapidly early in this month. *Pennington* (C.). Dates of first flowering still in advance of ordinary years. 17th. Cut first rose on wall. *Buckhorn Weston* (C.). Dog Rose in flower earlier than

in any year since 1862. *Hodsock* (D.). 14th. Horse chestnut in full bloom. *Tynron* (H.) 81st. Potatoes injured by frost, also ferns by wayside and in fields, no such severe frost so late in the spring for many years.

The Summer of 1890.

During June the weather was somewhat cold and sunless, but on the other hand there were many refreshing showers and but few cold nights, so that all crops made steady and uninterrupted progress. Towards the end of the month, however, there came heavy rains which greatly interfered with the hay harvest. July and August, the two months on which so much depends, as they are generally the warmest of the twelve, proved this year unseasonably cold and very wet. A great deal of the hay crop was consequently badly damaged, while much corn was beaten down and otherwise injured by the persistent and often heavy rainfall. In many parts of the country the potato disease made its appearance unusually early, and at the end of the summer threatened to become general. Flowers were at no time abundant, but many varieties remained in blossom a much longer time than usual. The cool showery weather favoured the growth of trees, shrubs, grass and roots, as well as that of most vegetables.

Observers' Notes.

JUNE.—*Babbacombe* (A.). Haymaking began on the 16th; much hay was stacked by the 24th, but the heavy showers which afterwards prevailed interfered with the remaining harvest work. *Wells* (A.). 1st. First grass cut. *Pennington* (C.). 1st. Grass first cut. Very little hay carried at end of month. *Thurcaston* (D.). A cold month. Temperatures below 82° five times indicated by grass minimum. Roses much infested with aphides and larvæ. *Tynron* (H.). May brought forward, but June has delayed, blossom. *Durham* (L.). 28th. Gorse most beautifully in blossom.

JULY.—*Babbacombe* (A.). Haymaking interfered with by wet weather. Corn crops much laid and injured by frequent rains. *Westward Ho* (A.). Very cold and wet up to 18th. *Pennington* (C.). Haymaking furnished a fair crop, but it was indifferently harvested owing to constant rain. *Buckhorn Weston* (C.). The hay crop heavy but not harvested in good condition. *Thurcaston* (D.). Strawberries plentiful, and lasted longer than usual. *Cloughton* (F.). Honeysuckle and wild roses very abundant this summer.

AUGUST.—*Babbacombe* (A.). 9th. Hay harvest finished. Corn harvest much interfered with by continuously showery weather. *Pennington* (C.). Harvest operations much hindered by unsettled weather, and at end of month much still to be gathered in, especially barley. Pastures and lawns green throughout the summer. Bees swarmed and worked well early in the season, but suffered from the unsettled weather as well as from the inroad of wasps. Wasps numerous, butterflies scarce.

The Year ending August 1890.

The weather of the autumn, winter and spring, and of the first summer month (June) could scarcely have been more favourable for vegetation, but in general that of July and August proved altogether as unpropitious.

DISCUSSION.

Mr. BLANFORD inquired whether any steps had been taken to ascertain an average date of flowering, &c., of the various plants for the purpose of comparison.

Mr. WILSON said, respecting the question of average date of flowering, that one element of error might be eliminated by observers cultivating the wild flowers to be observed in their own garden. It was curious how one individual plant or tree was invariably ahead of all others of a similar kind. There was a Horse chestnut tree in Harpenden Village which was always a week or two earlier in leafing and flowering than others in the district, and so far as he knew its position was not more favourable than that of other trees. As regarded the crops, wheat grown at Rothamsted in 1890, on a field dressed with farm-yard manure, gave an exceptionally good crop, the highest of the forty years during which records had been kept. Apples and pears were scarce; plums very scarce; strawberries very abundant; gooseberries and currants about average; peaches good. He thought the plan followed at Montpellier, of having the test plants near the thermometer screen and regularly inspected, was the only safe one.

Mr. TRIPP thought it would be interesting if averages could be obtained. There was a valuable table of averages given in the *Cobham Journals*, kept by Miss Molesworth, but of course that would not be suitable for comparison with all places, as the average dates would vary in different districts. It would be interesting, too, to find out with regard to the potato crop, how far certain districts and certain different classes of potatoes were affected.

Mr. SYMONS gave a short history of the phenological observations, and stated that the matter had been brought under the notice of the Scientific Societies' Committee of the British Association at their meeting in the past autumn, when a long discussion had ensued which he hoped would result in the co-operation of the various local scientific societies scattered throughout the country. Phenological observations were much farther advanced on the Continent than in England. The question of the *cultivation* of plants had been argued over and over again, but there was this to be said about it, that a cultivated plant is taken away from its natural conditions, and placed amid artificial surroundings. At Montpellier there was a little garden of cultivated plants in close proximity to the thermometer screen, and it was the duty of the observer to note the daily progress of these plants. He was not prepared to say whether the plan was worthy of imitation or not.

Mr. MAWLEY, in reply, said that averages were very necessary for the purpose of comparison. He had not introduced them into the tables this year as he had intended, as it was the last time the same list of plants, birds and insects would be used. Next year a new and simpler system of observation would be adopted, and he would endeavour to obtain, as far as possible, approximate averages for all the plants, &c., on the new list. The observation of cultivated trees and plants would not be likely to afford comparable results, as the varieties of most of them were now so numerous, and the methods of cultivation so different.

THE CLIMATE OF HONG-KONG.

By WILLIAM DOBERCK, Ph.D., F.R.Met.Soc.

(Abstract.)

[Received July 30th.—Read December 17th, 1890.]

THE latitude of Hong-Kong being $22^{\circ} 18' N$, the Colony is situated within the tropics, but the winter is cool, its mean temperature being about 60° , whereas the mean temperature of the summer months rises a little above 80° . There is a large and well-marked annual variation of climate, but it is very hot in the sun all the year round. Palm trees, pomelos and oranges thrive here. Rice, sugar-canes and pine-apples are among the most extensively cultivated crops. Chinese fir trees and bamboos grow wild, and the latter attain to great size if allowed to grow. Banian trees are also common. Vines do not come to perfection as the winter temperature is not low enough to harden the wood.

In summer the dampness of the air is excessive; and Europeans suffer much from prickly heat, produced in consequence of the heat and dampness. The natives are also much subject to diseases of the skin, especially the different varieties of Tinea. Malarial fevers and diarrhoea are the worst hot weather diseases, the former chiefly of an intermittent type in summer. They are worst in August and September, when the Colony is under the influence of the high-pressure areas preceding and lying to the north of typhoons. In these areas the wind is light and the air descending, so that it is stifling, dusty, and probably full of bacteria. Want of sleep lays the foundation for diseases of the brain.

In autumn the dampness of the air decreases, and the temperature falls often rather suddenly when the North-east monsoon sets in. This causes affections of the chest and catarrhs, but there is very little consumption. Europeans enjoy almost an immunity from phthisis. Malarial fevers are now more of the remittent type. Small-pox is usually endemic, but occasionally it assumes an epidemic form, beginning in November and lasting till spring.

In winter dysentery—the dreaded scourge of the Pacific—occurs. This is the worst disease of the Chinese coast, as it tends to become chronic, or leads to abscess of the liver, which quickly terminates fatally. Cholera is not much feared out here, and does not often occur. In spring, simple continued fevers and rheumatism are common diseases.

The most unhealthy places in the Colony are situated in ravines between the hills, near marshy land or paddy fields. In those places the ague is deadly. Between one or two thousand feet up on the hills the air is much purer, and fever less common and of a milder type, which is, as a rule, easily cured by a few doses of quinine. To live at such a height is agreeable, as the air is cooler and fresher, although much damper than below, and frequently saturated with moisture in the summer.

At the Hong-Kong Observatory the cistern of the barometer is placed 109 feet, the bulbs of the thermometers 108 feet, the anemometer 149 feet, and the rain-gauge 105 feet, above mean sea-level. The bulbs of the thermometers are 4 feet, the rim of the rain-gauge 21 inches, and the cups of the anemometer 45 feet, above the ground.

At Victoria Peak the barometer is 1819 feet above mean sea-level. The bulbs of the thermometers are 4 feet, and the rim of the rain-gauge 1 foot, above the ground.

Tables I. and II. give the mean results of the principal elements at the Hong-Kong Observatory and at the Victoria Peak for the 5 years 1884-1888.

TABLE I.—HONG-KONG OBSERVATORY.—METEOROLOGICAL RESULTS, 1884-88.

(Barometer 109 ft. above mean sea level).

Months.	Barometer Reading reduced to 32° Fah.	Temperature.					Humidity.	
		Means.			Extremes.		Relative.	Tension of Vapour.
		Mean.	Max.	Min.	Max.	Min.		
	Ins.	°	°	°	°	°	o/o	In.
January ..	30°053	59·7	63·1	56·1	74·4	41·8	74	·391
February ..	30°042	55·3	58·2	52·1	70·0	40·6	78	·350
March ..	29·947	62·0	66·1	59·0	78·4	48·8	85	·481
April	844	69·6	74·4	67·1	84·8	56·5	86	·635
May ...	765	75·9	80·4	73·5	88·4	65·8	84	·765
June	648	80·2	84·4	77·5	89·3	69·2	83	·861
July	611	81·5	85·5	78·1	92·9	73·8	83	·890
August ..	637	80·9	85·0	77·3	90·4	72·2	83	·874
September	722	80·3	84·3	77·0	90·7	70·8	76	·793
October..	29·903	76·0	79·1	72·7	86·1	60·8	70	·639
November	30°012	68·9	73·4	65·7	82·6	55·0	64	·462
December	30°063	62·4	66·8	59·3	76·3	44·8	64	·370
Year	29·854	71·1	75·1	67·9	92·9	40·6	78	·626

Months.	Rainfall.			Mean hourly velocity of the wind.	Amount of Cloud.	Sunshine.	
	Average	Greatest fall in one day.	Mean No. of hours during por. tion of which rain fell.			Average.	Per-centage of possi-ble dura-tion. ¹
	Ins.	Ins.		Miles		Hours.	
January	2·30	3·920	43	15·5	6·7	131·2	42
February	2·70	1·265	73	16·3	8·1	63·2	21
March	4·85	3·580	67	16·7	8·3	82·4	26
April	7·68	5·210	80	15·1	8·0	115·3	35
May	7·45	5·975	73	13·5	7·8	138·1	39
June	16·47	12·630	120	13·5	7·7	155·1	42
July	15·50	13·480	128	11·8	6·9	194·2	51
August	14·85	6·555	96	9·5	6·5	200·0	54
September	7·72	5·855	68	12·1	5·6	212·2	60
October	2·99	2·240	28	14·4	4·3	231·3	69
November	0·77	0·925	20	13·5	4·4	214·9	73
December	1·60	1·670	29	13·0	4·0	208·7	65
Year	84·88	13·480	825	13·7	6·5	1946·6	48

¹ Four years only 1885-8.

TABLE II.—VICTORIA PEAK.—METEOROLOGICAL RESULTS, 1884-88.

(Barometer 1819 ft. above mean sea-level.)

Months.	Barometer Reading re- duced to 32° F.	Temperature.					Humidity.		Rainfall.		Mean Hourly Velocity of the Wind.
		Means.			Extremes.		Relative.	Tension of Vapour.	Average.	Greatest Fall in one day.	
		Mean.	Max.	Min.	Max.	Min.					
	In.							In.	In.	In.	Miles.
January	28.262	54.1	57.9	50.5	69.1	36.0	86	.371	3.88	5.01	25
February	.232	49.9	53.5	46.3	67.8	35.3	90	.333	3.57	1.75	25
March ..	.187	58.4	62.4	54.4	72.3	42.0	90	.461	4.84	5.10	24
April ....	.105	65.3	68.7	61.9	76.5	47.8	93	.594	8.72	8.40	25
May	28.055	70.2	73.1	67.6	78.3	57.2	94	.705	8.38	4.85	24
June	27.960	73.6	76.0	71.3	81.3	64.8	95	.794	19.34	14.50	26
July ....	.928	75.3	77.9	73.2	84.2	69.8	93	.822	18.00	14.56	24
August ..	27.953	75.0	77.7	72.7	82.9	67.0	93	.811	17.70	9.20	23
September	28.025	74.3	77.5	71.6	82.5	66.0	88	.750	6.51	6.50	23
October ..	.178	69.8	73.4	66.6	79.7	58.3	84	.622	2.75	1.71	24
November	.254	62.6	66.7	58.9	74.9	44.0	77	.458	1.16	1.20	23
December	28.277	56.2	60.6	51.8	69.0	40.1	77	.360	1.99	2.36	24
Year ..	28.118	65.4	68.8	62.2	84.2	35.3	88	.590	96.84	14.56	24

The highest temperature of the air occurs about 2 p.m., and the lowest between 6 a.m. and 7 a.m. in winter, and about 5 a.m. in summer.

The relative humidity values vary inversely as the temperature, while the actual amount of vapour is greatest a few hours after sunset and least shortly after sunrise. In winter there is nearly as much vapour at the Peak as at the Observatory, but in summer there is less.

The amount of bright sunshine is greatest in November and smallest in February. The daily maximum occurs about noon, and there is more sunshine in the afternoon than in the forenoon.

The hourly intensity of rainfall is greatest about noon and least about midnight, while the rainfall itself is a maximum shortly after sunrise and a minimum about sunset. Most rain falls in June and least in November. There falls on an average $\frac{1}{4}$ more rain on top of the Peak than at the Observatory, but in September and October, when the rain is chiefly collected during typhoons, there appears to fall less on the top of the Peak.

Rain falls more frequently at sunrise than at sunset, particularly in summer.

The mean wind velocity is greatest in spring when the Trade wind and the Easterly monsoon co-operate, and least in August when the Southerly monsoon is blowing. At the Peak the wind blows nearly as strong during summer as during winter. The wind is strong about 1 p.m. and least shortly after sunset. This causes, during the hottest months of the year, a secondary maximum of temperature shortly after sunset which is particularly well marked during cloudy weather. In winter, at times when the North-east Trade winds blows strongly, its force is often greatest at night, or during the early morning hours.

Fogs are common in March, and occur also during typhoons in August and September. Electric phenomena prevail in August. Unusual visibility of distant objects prevails when the air is frequently cleared from dust by heavy rain in July. Dew is common in August, when also halos and coronæ are most frequent. Rainbows are comparatively rare in hot countries, where the rain is so heavy and the sun usually too high in the sky. Hail is unknown here.

Cumulus is the common cloud in China. Cirrus is most frequent during typhoons, and cumulo-stratus during the hottest part of the year.

The amount of cloud is greatest in March and least in December. On an average there are more clouds at sunrise than about midnight. But looking at the different seasons, it is seen that in summer the amount is greatest in the afternoon and least about midnight, while in winter the amount is greatest during the early morning hours and least in the afternoon.

The daily maximum of rain was exceeded in 1889, when there fell 22·535 inches of rain between 8.80 p.m. on the 29th May, and the same time on the 80th.

At the Peak, the minimum thermometer exposed one inch above the grass registered below freezing point. That never occurs at sea-level in Hong-Kong, but a little farther inland, as at Canton, frost is not unknown.

The barometric tide is large in winter (when the air is dry) and small in summer (when it is damp). The mean diurnal variability of temperature—the mean of the differences of temperature of each day and the next—is greatest in winter. The number of days on which at least 0·01 inch of rain fell at the Observatory was a minimum in November and a maximum in June and July. The hourly intensity of rain is greatest in July and least in February. The directions whence clouds in different levels come, together with the wind directions, prove the direction of the wind to veer on ascending in the atmosphere. The height of the lower clouds is least in April and greatest in November.

The rate at which the temperature falls on ascending the atmosphere is least in March, when the relative humidity is great, and the clouds are low, and it is greatest in June.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

NOVEMBER 19TH, 1890.

Ordinary Meeting.

BALDWIN LATHAM, M.Inst.C.E., President, in the Chair.

WILLIAM FREDERICK BLAY, Claremont House, Highgate, Walsall ;
THOMAS HENRY NEWPORT DAVIS, Orleton, near Tenbury ;
WILLIAM GREATHED, 67 Chancery Lane, W.C. ;
ERNEST WILLIAM GREG, Higher Dunscar, Bolton ;
JOSEPH HORROCKS, 10 Union Street, Southport ;
WILLIAM LAWFORD, M.Inst.C.E., Parliament Mansions, S.W. ;
Major SOMERSET HENRY MAXWELL, Arley Cottage, Mount Nugent, Co. Cavan ;
Sir JOHN SHELLEY, Bart., J.P., Shobrooke Park, Crediton ; and
ROBERT STODART WYLD, Jun., M.Inst.C.E., F.G.S., Liverpool Corporation
Waterworks, Oswestry,
were balloted for and duly elected Fellows of the Society.

The PRESIDENT delivered an Address on "THE RELATION OF GROUND WATER TO DISEASE." (p. 1.)

On the motion of Dr. WILLIAMS, seconded by Mr. H. J. MARTEN, the thanks of the Society were given to the President for his Address.

DECEMBER 17TH, 1890.

Ordinary Meeting.

HENRY F. BLANFORD, F.R.S., Vice-President, in the Chair.

TREVOR FOWLER, L.R.C.P., Epping ;
ARTHUR GREG, Eagley, Bolton ; and
HENRY WOOLCOCK, Assoc.M.Inst.C.E., Rickerby House, St. Bees,
were balloted for and duly elected Fellows of the Society.

Mr. J. S. HARDING and Mr. H. S. WALLIS were appointed Auditors of the Society's Accounts.

The following Papers were read:—

"NOTE ON A LIGHTNING STROKE PRESENTING SOME FEATURES OF INTEREST."
By ROBERT H. SCOTT, M.A., F.R.S. (p. 18.)

"NOTE ON THE EFFECT OF LIGHTNING ON A DWELLING HOUSE AT TWICKENHAM,
SEPTEMBER 23RD, 1890." By ARTHUR BREWIN, F.R.Met.Soc. (p. 19.)

"WIND SYSTEMS AND TRADE ROUTES BETWEEN THE CAPE OF GOOD HOPE AND
AUSTRALIA." By Capt. M. W. C. HEPPWORTH, F.R.Met.Soc. (p. 21.)

"REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1890." By EDWARD
MAWLEY, F.R.Met.Soc. (p. 27.)

"THE CLIMATE OF HONG-KONG." By W. DOBERCK, Ph.D., F.R.Met.Soc.
(p. 87.)

CORRESPONDENCE AND NOTES.

REMARKABLY LOW TEMPERATURE ON NOVEMBER 28TH, 1890.

MR. S. ROSTON, F.R.Met.Soc., of Beddington, Surrey, made the following interesting notes on the remarkably low temperature which occurred on the afternoon of November 28th, 1890:—

"Early a.m., overcast and snowing, small flakes. Wind East-south-east, gentle. Barometer 29.90 ins., rising. I was struck with low temperature (9.20 a.m. 22°·0), with overcast sky and snow. In town at 1.30 p.m. When I crossed St. James's Park the water was open and the thermometer opposite Marlborough House read 24°·0, but on returning at 3.40 the thermometer read 21°·0, and the water was frozen from end to end. I left Victoria at 4.5 p.m. At Balham the sky was clearing. At Carshalton the sky was cloudless with haze from excessive cold; snow musical, my beard froze at once, and my ears were very painful. Carshalton pond smoked like a cauldron. In Acres Lane I heard a wood fence cracking. I arrived home at 5.15, and found minimum temperature had been 2°·8, it was then 5°·0; the thermometer on the snow had been —8°·0, it was then —5°·0. Mist came up covering sky, and the temperature rose fast; at 6 o'clock it was 10°·0; 7 o'clock, 12°·8 and cloudy; 9 o'clock, 15°·2; and 11 o'clock, 15°·2.

"My gardener told me that he had seen the temperature 8°·0 in the Stevenson screen at 4.45 p.m.; at 4.30 it was 5°·0; at 3 o'clock, 18°·0; and 1 o'clock p.m. 22°·0. The sky cleared and the snow stopped about 2 o'clock, the temperature then fell very fast after 3 o'clock. The minimum must have been about 5 p.m., the extreme cold lasting only a few minutes."

JAMAICA METEOROLOGY.

MR. Maxwell Hall has given in the *Supplement to the Jamaica Gazette*, Vol. XIII. No. 82, the results of the meteorological observations made at Kingston during the ten years ending May 1890. The mean results for the whole period are as follows:—

Month.	Barometric Pressure reduced to Sea-Level.	Temperature.					Wind, S.E. Miles per diem.	Vapour.		Amount of Cloud.	Rainfall.	
		Mean.	Mean Max.	Mean Min.	Mean Range.	Dew- Point.		Humidity.	Kingston.		The Island.	
	Ins.	°	°	°	°			%		In.	In.	
January	30.054	74.6	86.4	66.8	19.6	68	66.7	78	2.9	.96	3.87	
February .....	.049	74.7	85.8	66.8	19.0	72	66.7	78	2.7	.32	2.62
March .....	.034	75.8	85.7	67.8	17.9	77	67.6	77	2.9	1.59	2.88
April	30.008	77.9	86.5	69.8	16.7	68	69.1	75	3.9	1.02	4.18	
May	29.979	79.4	87.2	72.4	14.8	74	71.4	78	5.6	6.00	8.40	
June	30.000	80.8	88.5	73.8	14.7	115	72.8	78	5.7	5.51	7.83	
July	30.024	81.1	89.7	73.5	16.2	103	72.5	76	5.2	2.15	4.32	
August	29.983	80.4	89.4	73.2	16.2	80	73.0	79	5.5	4.09	6.83	
September .....	.956	80.1	89.7	73.3	16.4	70	73.1	80	6.2	3.59	6.86
October .....	.937	78.9	88.9	72.1	16.8	56	72.2	81	5.8	4.69	7.84
November	29.962	77.8	88.9	70.7	18.2	53	70.1	78	4.4	1.22	5.07	
December	30.005	75.7	87.0	68.4	18.6	57	68.0	78	3.8	1.50	5.60	
Year.....	29.999	78.1	87.8	70.7	17.1	89	70.3	78	5.5	32.64	66.30	

From June 1880 to December 1886 the readings were taken at intervals of eight hours, viz. at 7 a.m., 8 p.m. and 11 p.m. local mean time; the daily means were assumed to be the means of the three eight-hourly readings; but since

January 1887, the readings have been taken at 7 a.m. and 8 p.m. only; and the daily means were deduced by applying to the 7 a.m. and 8 p.m. readings their proper reductions; and from the daily means the monthly means have been deduced.

In the seventh column of the Table the wind is stated to be South-east, and this is in consequence of the regularity of the daily sea-breeze, which is almost invariably South-east at Kingston.

The highest temperature recorded during the ten years was $96^{\circ}1$ on September 12th, 1880; and the lowest $56^{\circ}7$, on December 4th, 1887.

RECENT PUBLICATIONS.

AMERICAN METEOROLOGICAL JOURNAL. October-December 1890. Vol. VII. Nos. 6-8. 8vo.

Contains, among other information, the following articles:—Cyclical periodicity in meteorological phenomena; by E. D. Archibald (7 pp.).—Accessory phenomena of cyclones; by H. Faye (22 pp.).—State Tornado charts; by Lient. J. P. Finley (4 pp.). The State dealt with herein is Nebraska.—Temperatures in and near forests; by M. W. Harrington (7 pp.).—Meteorological Congress at Limoges, France; by A. L. Rotch (5 pp.). This is an account of the proceedings at the meteorological section of the French Association for the Advancement of Science which was held at Limoges, August 7th to 14th, 1890.—Espy's Experiments on Storm generation; by Prof. W. Ferrel (8 pp.).—The Upper Yukon and the Mackenzie (14 pp.).—The thunderstorms and water spout at New Haven, Conn., on October 19, 1890; by H. J. Cox (4 pp.).—Temperature in anticyclones and cyclones; by Dr. J. Hann (8 pp.). This is a translation of Dr. Hann's paper in the *Meteorologische Zeitschrift*, June 1890.—Observations and studies on Mt. Washington; by Prof. H. A. Hazen (5 pp.).—Cyclones and tornadoes in North America; by J. Brucker (6 pp.).—The cooling of dry and moist air by expansion; by Prof. C. F. Marvin (6 pp.).

BIBLIOGRAFÍA METEOROLÓGICA MEXICANA que comprende las Publicaciones de Meteorología, Física del Globo y Climatología hechas hasta fines de 1889. Formada por RAFAEL AGUILAR SANTILLÁN. 8vo. 1890. 48 pp.

This is a valuable catalogue of all the papers bearing on the meteorology of Mexico which have been published up to the end of 1889.

DAS WETTER. Herausgegeben von Dr. R. ASSMANN. December 1890. 8vo.

This number contains a reprint of a very valuable article by Dr. Hann, "Warum es auf hohen Bergen kalt ist." Why is it cold on high mountains? This first appeared in the *Deutsche Revue*. From Dr. Hann's experience in dealing with Alpine observations, anything from his pen must command attention, and in the present article he deals with the results of solar radiation obtained by Violle and by Langley, and ends by pointing out why table lands are much warmer than isolated peaks of the same altitude, and how the essential characteristic of mountain peak climate is intense cold in summer and relative warmth in winter. He concludes by saying that if a peak of the height of the Himalayas existed among the Alps there would be no annual change of climate at the top, the winter there would be perpetual.

MEMOIRS AND PROCEEDINGS OF THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY. Fourth Series. Vol. III. 8vo. 1890.

Contains two papers on meteorological subjects, viz. (1.) The Levanter clouds at Gibraltar; by J. J. Ashworth. This phenomenon is very similar to the Helm Wind of Cross Fell, in Cumberland.—(2.) Meteorology at the Sea-side; by Dr. W. G. Black.

METEOROLOGISCHE ZEITSCHRIFT. Redigirt von Dr. J. HANN and Dr. W. KÜPPEN. October-November 1890. 8vo.

The principal articles are:—*Untersuchungen über die Temperatur und die Feuchtigkeit der Luft unter, in und über den Baumkronen des Waldes, sowie im Freilande*; von F. Eckert (7 pp.).—*Beobachtungsergebnisse der neueren forstlich-meteorologischen Stationen im Deutschen Reiche*; von F. Eckert (11 pp.). These two papers take up most of the October number. The first is a summary of a report by Dr. Lorenz Liburnau and the author on the results obtained from the Austrian forest stations. Some new forms of apparatus were used, the thermometers were Osnaghi's "turn over," the hygrometers were chemical, with aspiration. The chief contrast shown by the results to those of German stations is as regards the aqueous vapour at Ried, a station lying on the edge of the dry region of the Black Sea, where the wood shows an excess of moisture as compared with land outside. The second paper is a detailed comparison of the results from German stations *inter se*, and with Austrian stations.—*Isogradienten-Karten für die ganze Erdoberfläche*; von J. Kleiber (11 pp. and 2 plates). This is an attempt by a Russian Professor to give charts of the general gradients. The present paper deals only with January, and two maps are given, one of the North and South, the other of the East and West gradient. In each map two colours are used, one for North to South, the other from South to North, and so on. On the map for North and South gradients the boundaries between the two regions lie along parallels of latitude, in the other map they are less regularly arranged. Charts for July and for the year are promised.—*Die Anwendung des Gesetzes der Flächen auf atmosphärische Strömungen*; von Prof. Max Möller (7 pp.).—*Ein Wunsch in Betreff der Ergebnisse der Anemometer-Aufzeichnungen*: von Dr. J. M. Pernter (2 pp.). The author, who has been discussing the anemometrical data from the Sântis and other mountain stations, finds the reductions so laborious that he proposes that all observatories should publish tables giving the hourly velocity and frequency for the 16 points of the compass, and he gives a specimen table.

PHILOSOPHICAL MAGAZINE. December 1890. 8vo.

Contains:—On the General System of Winds on the Earth; by Werner von Siemens (9 pp.). This is a translation of an article by the author from the *Sitzungsberichte der Königlich preussischen Akademie der Wissenschaften zu Berlin*, Vol. XXX., 1890. The author says: The theory of the general system of winds may be summed up in the following statements:—

1. All motions of the air depend upon disturbances of the indifferent equilibrium of the atmosphere, and tend to bring about its restoration.
2. These disturbances are caused by the superheating of the strata of air lying nearest to the earth's surface through solar heat, by unsymmetrical cooling of the upper layers of the air through radiation, and by the piling up of masses of air in motion through obstructions occurring to the current.
3. The disturbances are balanced by means of ascending currents, which possess an acceleration of such a kind that the increase of velocity of the air is proportional to the diminution of its pressure.
4. Down-currents of equal magnitude correspond to the up-currents, and in these the velocity of the air is retarded in the same proportion as that of the up-flow is accelerated.
5. If the heating of the lower strata of air takes place within a limited area, a local up-flow occurs reaching to the uppermost regions of the air, and presenting the appearance of whirling columns with ascending spiral currents of air inside, and similarly directed descending currents outside. The result of these whirling currents is a diffusion of the surplus heat of the lower strata through which the adiabatic equilibrium is disturbed, to the whole column of air which took part in the whirling motion.

6. When the sphere of disturbance of the indifferent (or adiabatic) equilibrium is very extended, compromising for instance the whole torrid zone, the equalisation of temperature can no longer be effected by local ascending whirling currents, but these must comprise the whole atmosphere. The conditions are the same as with local currents, viz. an accelerated ascent and retarded descent of the air, so that the velocity of the air due to the action of the heat is at the different latitudes approximately inversely proportional to the air-pressure prevailing there.

7. As the air of every latitude rotates with approximately the same absolute velocity in consequence of the constant meridional currents which the heat produces and maintains, and meridional combine with the terrestrial currents to form the great system of currents of air surrounding the whole earth, whose function it is to give a share of the surplus heat of the torrid zone to the whole atmosphere, by transferring equatorial heat and moisture to the middle and higher latitudes, and by originating local air-currents in them.

8. These latter are due to the local production of alternate increase and decrease of pressure through the disturbance of the indifferent equilibrium in the upper strata of the atmosphere.

9. The maximum and minimum air-pressures are effects of the temperature and velocity of currents of air in the higher strata of the atmosphere.

From what precedes, the investigation of the causes and effects of the disturbance of the indifferent equilibrium of the atmosphere may be considered as one of the most essential problems of meteorology, and the investigation of the geographical origin of the air-currents passing over us on their way to the poles as the most important problem in the prognostication of the weather.

RESULTS OF RAIN, RIVER, AND EVAPORATION OBSERVATIONS MADE IN NEW SOUTH WALES DURING 1889. H. C. RUSSELL, B.A., C.M.G., F.R.S., Government Astronomer. 1890. 8vo. 183 pp. and 4 plates.

The record of the rainfall for 1889 shows that the year was a most favourable one. In the central parts of the Colony the rainfall for the three first months of the year was rather light, but in much of the Western, Southern, and Coast districts the rainfall was fairly abundant in these months, while for the remainder of the year the rainfall was abundant with scarcely any exception. All the tributaries of the Darling began to rise about the middle of April, and at the end of May a second and greater flood came on.

In May a phenomenal rainstorm came on, particularly in the metropolitan district, where it was heavier than any previous rainstorm since 1845. Over 20 inches fell in four days at the Observatory, and it is noteworthy that from 10 to 15 miles west of the Observatory it was much heavier, ranging from 23 to 27 inches in the same time. Fortunately the heaviest part of this storm was confined to the Metropolitan district, where, owing to the free course to tidal water, no serious floods occurred, but the rain was heavy enough over the Hawkesbury and Hunter rivers to produce high floods. The heaviest previous rainfalls at South Head, Sydney, were 20·12 ins. on April 29th, 1841, and 20·41 ins. on October 15th, 1844.

SYMONS'S MONTHLY METEOROLOGICAL MAGAZINE. Vol. XXV. Nos. 297-299. October-December 1890. 8vo.

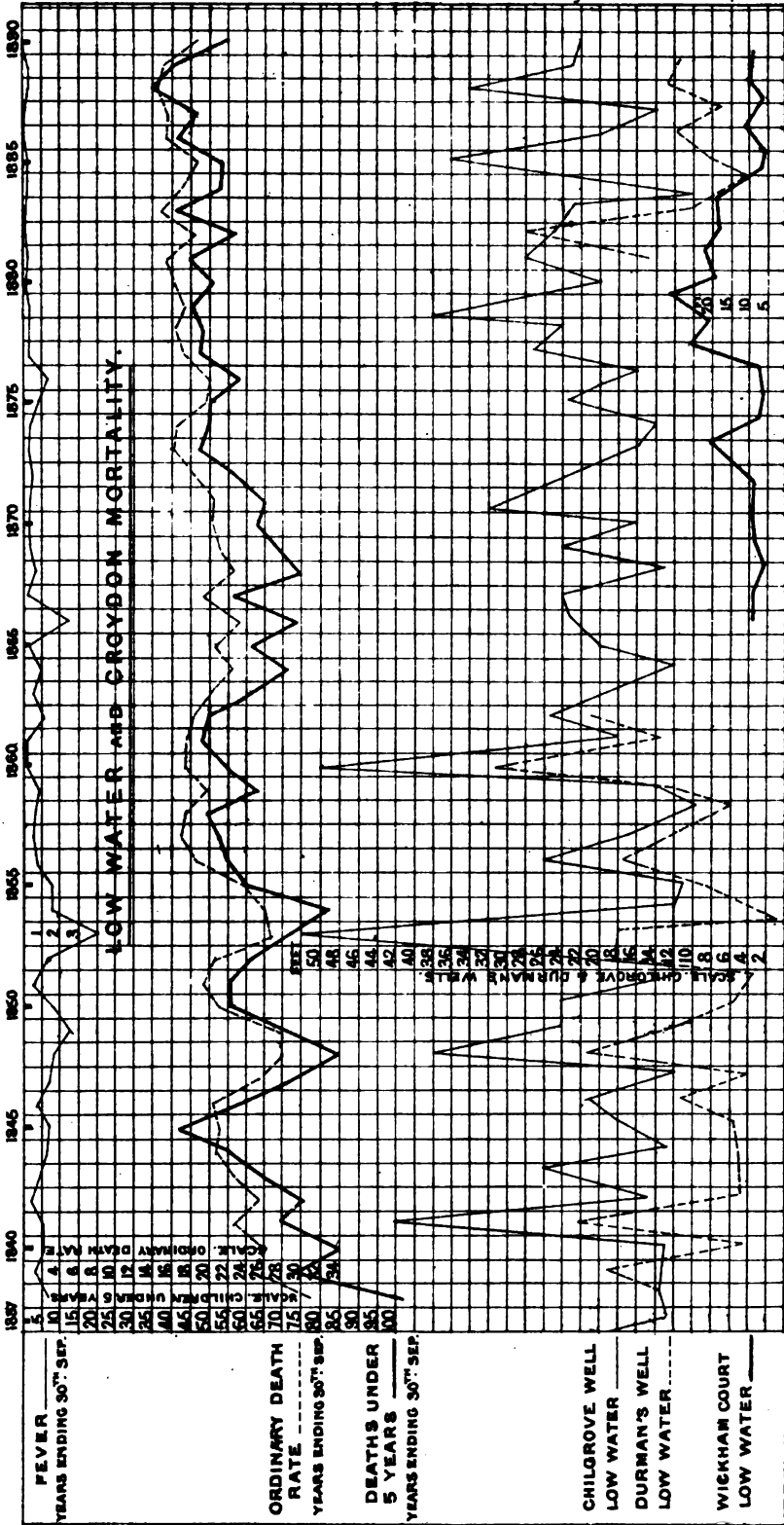
The principal articles are:—The Autumn Congresses (8 pp.). This gives an abstract of the meteorological papers read at the Meeting of the British Association at Leeds in September 1890.—Heavy hourly rainfall on Ben Nevis; by R. C. Mossman (1 p.).—Barometric Depressions; by Rev. G. T. Ryves, Prof. H. A. Hazen, Rev. J. Slatter, Rev. W. C. Ley, and W. H. Dines (4 pp.).—Hail Insurance (2 pp.).—Sharpest Frost in October for half-a-century (2 pp.).—Greenwich mean temperatures; by G. von U. Searle (1 p.).—Excessive frost in November (7 pp.). (See note by Mr. Rostron above on p. 42.)

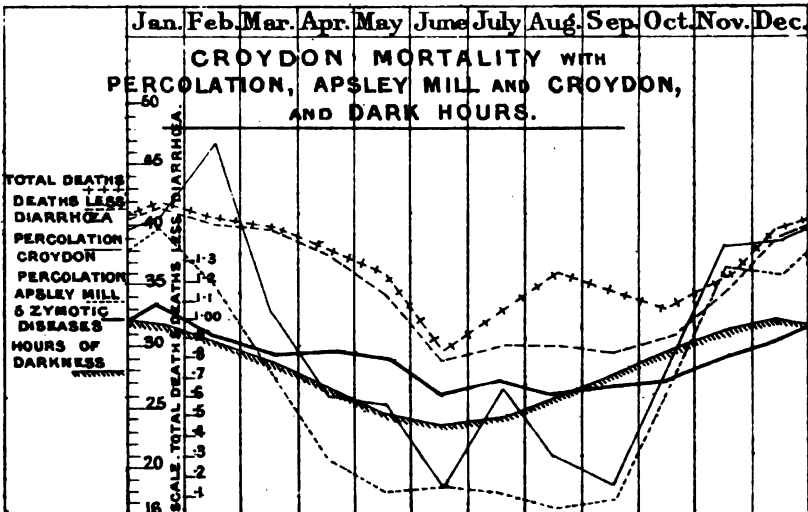
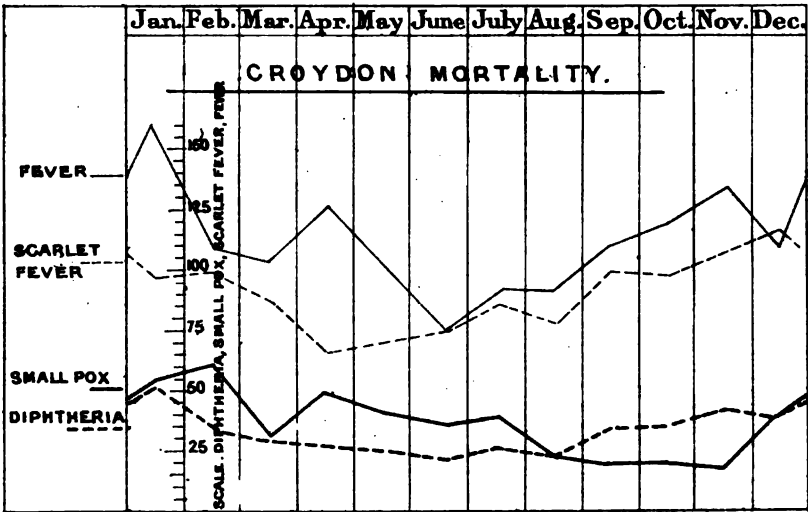
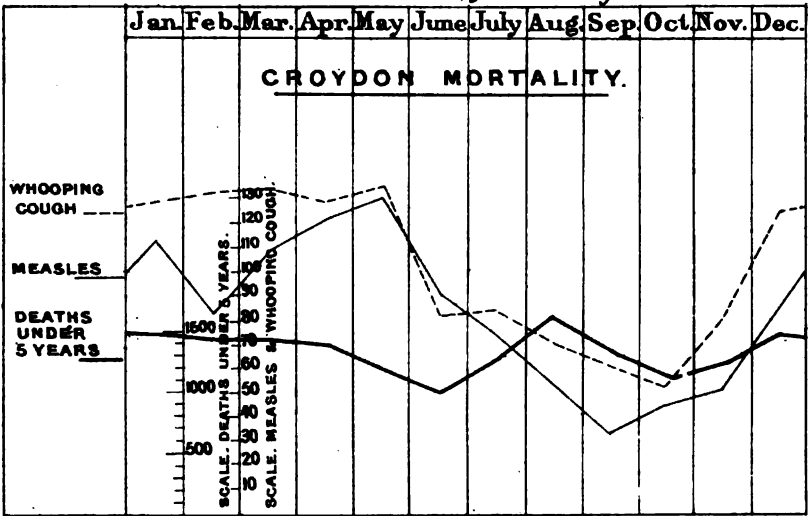
TRANSACTIONS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS. Vol. XXIII.
No. 448. 8vo. 1890.

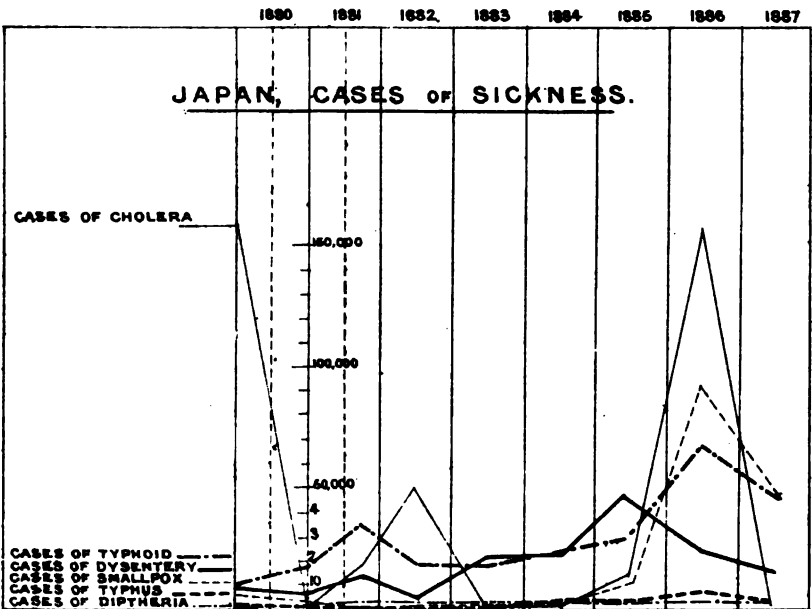
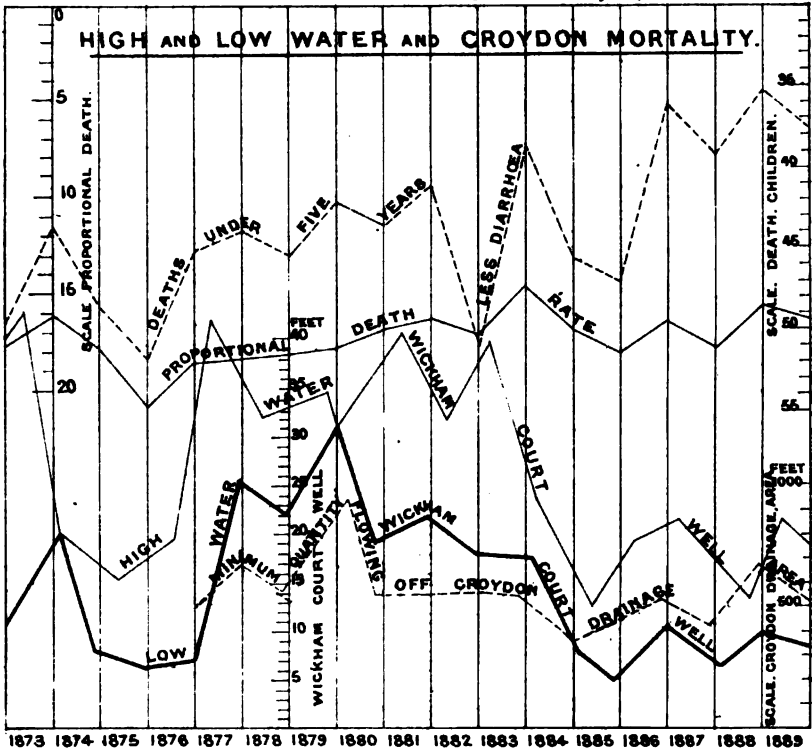
This contains a paper by Mr. F. A. Velschow "On the cause of Trade Winds" (8 pp. and 2 plates).

TRANSACTIONS OF THE SANITARY INSTITUTE. Vol. X. 1888-9. 8vo. 1890.
876 pp. .

This contains an account of the proceedings at the Congress held at Worcester in September 1889. In the Section of Chemistry, Meteorology and Geology, the President, Dr. J. W. Tripe, gave an exhaustive address on "Winds, with some remarks on their sanitary effects" (16 pp.).—Surgeon-Major W. G. Black also read a paper on "Meteorology at the Sea-side" (12 pp.)

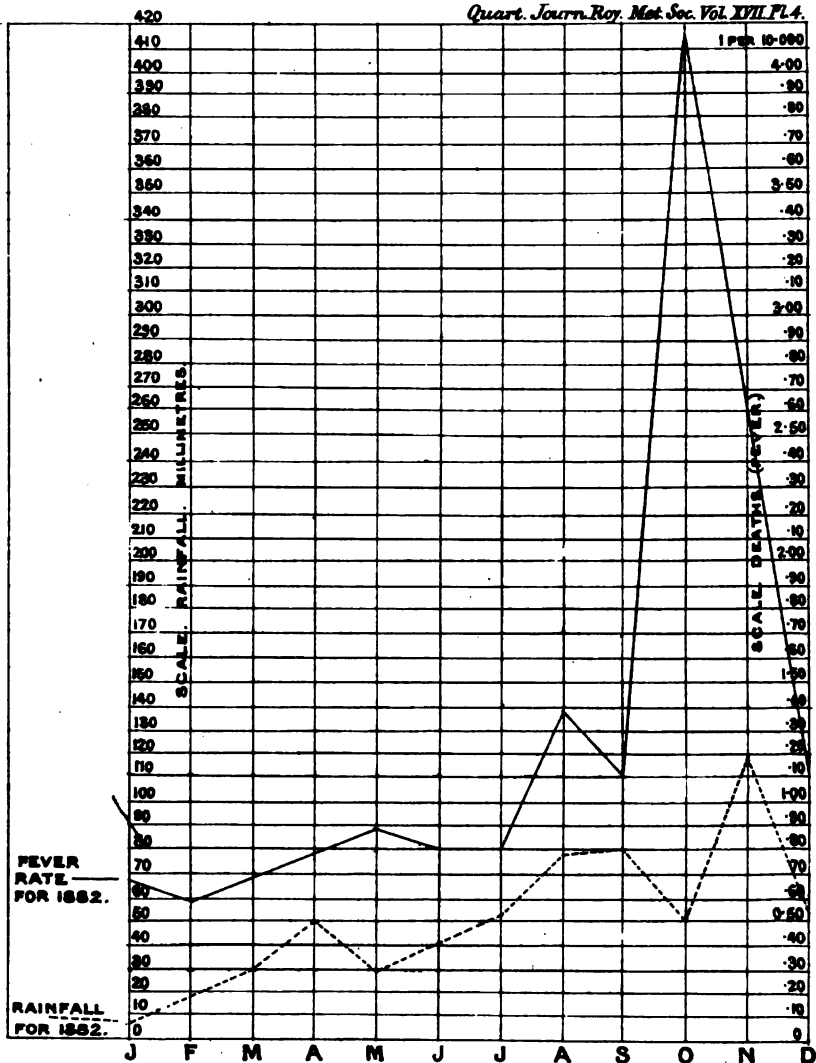




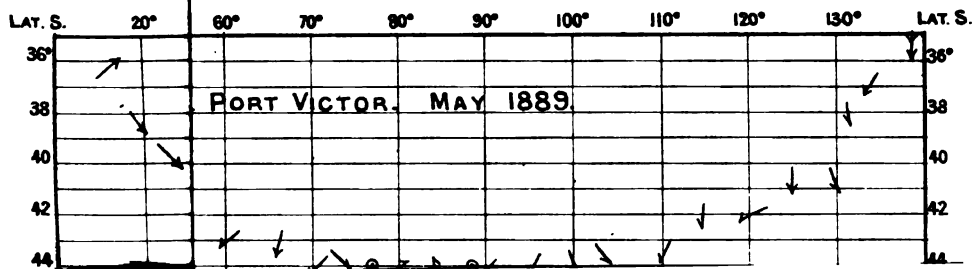


PARIS. RAINFALL AND TYPHOID FEVER.

Quart. Journ. Roy. Met. Soc. Vol. XVII Pl. 4.



HOPE AND AUSTRALIA.



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Quarterly Journal
OF THE
**ROYAL
METEOROLOGICAL
SOCIETY.**

EDITED BY A
COMMITTEE OF THE COUNCIL.

APRIL 1891.
VOL. XVII. No. 78.

LONDON :
EDWARD STANFORD, 26 & 27 COCKSPUR ST., CHARING CROSS, S.W.;
WILLIAMS AND STRAHAN, 7 LAWRENCE LANE, CHEAPSIDE, E.C.

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Royal Meteorological Society.

ESTABLISHED 1850. INCORPORATED BY ROYAL CHARTER, 1866.

OFFICE :—22 GREAT GEORGE STREET, WESTMINSTER, S.W.

SESSION 1891.

ORDINARY MEETINGS at 7 p.m.

JANUARY.....	21	1891.	MAY	20	1891.
FEBRUARY	18	"	JUNE	17	"
MARCH	18	"	NOVEMBER	18	"
APRIL	15	"	DECEMBER	18	"

ANNUAL GENERAL MEETING.—JANUARY 20, 1892.

By permission of the Council of the Institution of Civil Engineers, the above Meetings will be held at 25 GREAT GEORGE STREET, WESTMINSTER, S.W.

NOTICE.

THE LIBRARY AND OFFICES of the Society, 22 Great George Street, Westminster, are open daily from 10 a.m. to 5 p.m.; Saturdays, 10 a.m. to 2 p.m.

THE SOCIETY is not responsible for the views and opinions advanced in the *Quarterly Journal*.



QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY.

VOL. XVII.

APRIL 1891.

No. 78.

REPORT OF THE COUNCIL FOR THE YEAR 1890.

THE progress of the Society during the year has been satisfactory, as the Papers have been of good quality and sufficiently numerous, the number of Fellows has increased, and the income, although somewhat less than in 1889, was considerably more than £1,000. The expenditure was, however, in excess of the income, owing to the whole cost of the Catalogue being charged against this one year. The ordinary office work, including the reduction and publication of the returns from the Society's stations, has been carried on with regularity, as well as the continued discussion of the phenomena attendant on the thunderstorm records for 1888-89.

New Premises Fund.—In the Report for the year 1889, the Council stated that "the rooms occupied by the Society have been whitewashed, painted, and repaired, and other improvements made in the accommodation, but this is insufficient for our wants. A Committee has been therefore appointed to make inquiries in the neighbourhood, but the rent asked for suitable rooms was too high. In these circumstances the Council have initiated a New Premises Fund, by investing the sum of £50 as a commencement towards the amount necessary to provide better accommodation. The Council hope that many of the Fellows will assist in carrying out this scheme." In 1890 a further sum of £50 was contributed by the Society. Circulars were sent out to all the Fellows, and a considerable number, as per annexed list, have responded liberally, including the President, who has assisted with £52 10s., the late President, Dr. Marcet, with £50, and Dr. C. T. Williams with £100. The total promised, including the £100 from the Society's funds, amounted to £1,110 18s., of which sum £911 1s. has been paid. This sum is inadequate to the purchase of a long lease of suitable premises, but subscrip-

tions have not yet been received from all the Fellows. The interest upon the sum already received, when added to the amount now paid for rent, with the £50 which it is hoped will be annually contributed from the Society's funds, will enable the Council to take rooms more worthy of the Society, and this they expect to do shortly.

New Catalogue of Library.—The Council referred in the Report for 1889 to the preparation of a new Catalogue of the Library, which was very necessary, inasmuch as the last Catalogue was compiled in 1876, and since that year a very considerable number of new works had been presented to or purchased by the Society. The hope was expressed that it would be completed in 1890, and that it would be creditable to the Society and useful to meteorologists. The Catalogue has been printed and bound and circulated gratis to every Fellow, at a cost of about £250. This has been a heavy charge on the Society's finances for the year, as the whole amount has been paid out of income.

Committees.—The following Committees were appointed as usual:—

GENERAL PURPOSES COMMITTEE.—The President, Secretaries, Foreign Secretary, Treasurer, Messrs. Bayard, Brewin, Ellis, Marcet, and Williams.

EDITING COMMITTEE.—Messrs. Blanford, Inwards, and Scott.

STANDING REFEREE ON PAPERS.—Mr. Ellis.

ANNUAL EXHIBITION COMMITTEE.—The President, Secretaries, Messrs. Bayard, Ellis, Scott, and Strachan.

WIND FORCE COMMITTEE.—The President, Secretaries, Messrs. Chatterton, Dines, C. Harding, Laughton, Munro, and Scott; with Mr. Whipple representing the Kew Committee.

THUNDERSTORM COMMITTEE.—The President, Secretaries, Messrs. Abercromby, Beaufort, Blanford, Ellis, Inwards, and Scott.

THE LIBRARY CATALOGUE COMMITTEE.—Messrs. Eaton, Scott, and Symons, with Mr. J. S. Harding, Junr., as Editor.

Annual Exhibition of Instruments.—The Committee for arranging the Exhibition held several meetings, and eventually brought together a very good collection of instruments illustrating the application of photography to meteorology, and of photographs, &c., which were shown in the Library of the Institution of Civil Engineers. The subject was chosen as usual by the Council, and there were 96 exhibits, which were grouped as follows—Photographic Meteorological Instruments, 11; Instruments not previously exhibited, 8; Models, 4; Photographs and Drawings of Instruments, 26; and Photographs of Meteorological Phenomena, 47.

Thunderstorm Committee.—As the whole of the funds specially granted by the Royal Society for continuing the discussion of the Thunderstorms of 1888 and 1889 was spent in the early part of the year, application was made by Dr. Tripe for a further vote of £80 towards that object, which was granted in July. The times of first thunder (or of sheet lightning) for these years have all been extracted from the forms, tabulated and plotted on maps, in addition to the times of the occurrence of hail and of damage by lightning. The Committee also decided on having diagrams prepared showing the shape, path, cloud-motion, etc., of thunderstorms in the south-eastern portion

of England, *i.e.* south of 52° N., and east of 2° W. These are, as far as practicable, being prepared by Mr. Marriott as a special investigation, the cost of which will be paid out of the grant.

Inspection of Stations.—All the stations north of Lat. 52° N., which were not inspected in 1889, were visited this year, at a cost of £49 14s. 2d., towards which the Meteorological Office contributed as usual the sum of £25. Mr. Marriott reported that the stations, as a whole, were in a very satisfactory condition, the observers taking great interest in their work. These visits are considered to be of great importance, as observers often do not notice the growth of trees, &c. in the vicinity of the instruments, and the effects they have on the exposure; and the observers greatly value the inspections. The changes in the zeros of the thermometers were not so large as those found during last year's inspections. The dry and wet bulb thermometers, as well as the maximum, all mercurial, had risen in some instances as much as $0^{\circ}\cdot4$, whilst the minimum (spirit thermometers) had gone down $0^{\circ}\cdot2$ and $0^{\circ}\cdot8$ in five instances each. Mr. Marriott's report will be found in Appendix III. (p. 58).

Discussion and Working-up Observations.—The Council have long felt that their main object was not, as many suppose, the aggregation of an immense number of returns and their publication in the *Meteorological Record*; and they have from time to time taken into consideration the necessity for working up and discussing the observations made at the Society's stations. Part of this work has already been done in the Society's office, and Mr. Bayard has kindly undertaken the discussion of the observations for the ten years 1881-90, which, when completed, will be a valuable addition to the Society's work, and justify to a great extent the time and money spent in obtaining, comparing, and reducing the records of the climatological stations.

Alterations in Stations.—The alterations in the Stations have been more numerous than usual this year. Observations have been discontinued at Cramlington and Oakamoor, whilst they have been accepted from Chelmsford; Cromer; Great Malvern; Great Thurlow, Suffolk; Lynsted, near Sittingbourne; Portsmouth; Rothbury; South Molton; Tunbridge Wells; and Wryde, near Peterborough. Observations from these stations will add considerably to the value of the *Meteorological Record*, and can be published without making any increase in the number of its pages.

Wind Force Committee.—In May last this Committee reported, and the Council adopted the Report, that in their opinion simultaneous experiments should, if possible, be carried out with the following instruments:—Robinson's Anemometer, Kew Pattern; Richard's; Dines' Helicoid; Air Meters; Pressure Plates; Tube Anemometers; and Bridled Anemometers. The Committee further reported that until the foregoing experiments had been made, they were not prepared to recommend a mode of wind measurement. The Council refer with much satisfaction to the Paper published by Mr. Dines in the *Journal* on the results of his experiments on Wind Force.

Phenological Observations.—Mr. Mawley, after consulting some of the most experienced of the Society's past and present observers, and others

interested in the subject, presented a Report to the Council, suggesting that more valuable results would be likely to be obtained if the number of plants, &c., to be observed were considerably reduced. This Report having received the approval of the Council, new observation forms have been drawn up and printed for the future use of the observers. The Council hope that the reduction in the number of plants will enable the number of observers to be increased, which will greatly strengthen, and add to the value of, the annual reports.

The list of *Publications* for which the *Journal* or *Record* is given in exchange was carefully revised during the year, and the Council believe that the exchange is favourable to the Society, as numerous publications of Foreign Meteorological Observatories and Societies are thus secured, which could not otherwise easily be obtained.

The *Library* has been considerably improved during the year, not only by the addition of new books, but also of new shelves in it, as, in spite of the withdrawal of a number of non-meteorological books for presentation to Societies dealing with the subjects on which they treated, the shelf room was and is still most inadequate.

The *Meetings* have been very well attended during the year, and the discussions well sustained and fully up to the usual mark. If the attendance of the Fellows is to be taken as evidence of the vitality of the Society, as well as of increasing interest in Meteorology, the Council feel satisfied with the result of their labours.

The usual Table, showing the changes in the number of Fellows on the roll, is now presented, and shows that, although there has been a loss of 11 by death, including one Honorary Member, and 24 from other causes, yet the total is 6 above the number on December 31st, 1889.

Fellows.	Annual.	Life.	Honorary.	Total.
1889, December 31st...	401	181	17	549
Since elected	+ 39	+ 2	...	+ 41
Since compounded	- 1	+ 1	...	0
Deceased	- 9	- 1	- 1	- 11
Retired	- 14	...	...	- 14
Lapsed	- 8	...	...	- 8
Defaulters	- 7	...	...	- 7
1890, December 31st...	406	188	16	555

Deaths.—The Council have to announce with much regret the deaths of ten Fellows and one Honorary Member. The names are:—

Charles Octavus Budd, M.A.

elected Apr. 16, 1878.

Dr. C. H. D. Buys Ballot

„ June 17, 1874.

Thomas Henry Davis

„ Feb. 21, 1866.

William White Day, M.D.

„ Dec. 21, 1887.

Prof. Samuel Alexander Hill, B.Sc.	elected Feb. 20, 1884.
William Henry Paine, M.D.	„ Nov. 28, 1884.
Pickering Phipps, J.P.	„ Jan. 15, 1879.
Sir Warrington W. Smyth, M.A., F.R.S.	„ Mar. 25, 1855.
Admiral Sir Bartholomew James Sullivan, K.C.B.	„ Mar. 16, 1882.
Robert Tennent, F.R.S.E.	„ Nov. 20, 1878.
John Harrison Walker, L.R.C.P.	„ Jan. 18, 1888.

Finance.—Allowing for the expense of the Library Catalogue and the donation to the New Premises Fund as before-mentioned, the Council consider the financial state of the Society as satisfactory.

APPENDIX I.

Subscriptions promised towards the New Premises Fund.

JANUARY 21st, 1891.

	£	s.	d
Royal Meteorological Society...	100	0	0
Mr. E. G. Aldridge	1	0	0
Mr. E. B. W. Balme	2	2	0
Dr. R. Barnes	10	10	0
Mr. R. H. Barnes, B.A., F.L.S. (in three years)	3	3	0
Mr. L. L. T. Bateman	2	2	0
Mr. F. C. Bayard, LL.M.	10	10	0
Mr. W. M. Beaufort, F.R.A.S.	10	10	0
Mr. R. Bentley, F.R.G.S.	5	5	0
Mr. C. E. de Bertodano	5	0	0
Mr. T. N. Blake	2	2	0
Mr. H. F. Blanford, F.R.S.	10	10	0
Capt. E. G. Bourke, R.N.	2	0	0
Mr. W. L. Bourke, Assoc.M.Inst.C.E.	1	1	0
Mr. A. Brewin	10	10	0
Miss W. L. Brodie-Hall	1	1	0
Mr. C. J. Bromhead	5	5	0
Miss E. Brooke	25	0	0
Mr. E. H. S. Bruce, M.A.	1	0	0
Mr. F. C. Capel	10	0	0
Capt. A. Carpenter, R.N.	1	0	0
Mr. J. B. Charlesworth	20	0	0
Mr. A. W. Clayden, M.A., F.G.S.	5	5	0
Mr. J. Cleminson, M.Inst.C.E.	10	0	0
Maj-Gen. H. Clerk, R.A., F.R.S.	10	0	0
Mr. R. Cooke	10	10	0
Mr. W. S. Crimp, Assoc.M.Inst.C.E.	5	5	0
Mr. O. B. Cuville, F.C.A.	3	3	0
Mr. W. H. Dines, B.A.	2	0	0
Mr. J. Dover, B.A.	0	5	0
Mr. E. T. Dowson	9	0	0
Mr. P. Doyle, F.S.S.	3	3	0
Mr. E. E. Dymond, J.P.	10	10	0
Mr. E. M. Eaton, Assoc.M.Inst.C.E.	5	5	0
Carried forward	£313	17	0

				£	s.	d.
	Brought forward	...	...	313	17	0
Right Hon. Lord Ebury	...	...	...	10	10	0
Mr. F. B. Edmonds	...	...	...	10	0	0
Mr. W. Ellis, F.R.A.S.	...	...	...	5	0	0
Mr. Franklen G. Evans, J.P., F.R.A.S.	...	...	...	1	1	0
Mr. F. H. D. Eyre	...	...	...	1	0	0
Mr. C. C. Farr, B.Sc.	...	...	...	2	2	0
Mr. R. Field, B.A., M.Inst.C.E.	...	...	...	21	0	0
Mr. E. E. Glyde	...	...	...	2	0	0
Mr. F. Green, M.A.	...	...	...	10	0	0
Mr. W. Friese Greene (in two years)	...	...	...	10	10	0
Capt. W. N. Greenwood	...	...	...	1	1	0
Dr. T. E. Hale, B.A.	...	...	...	1	1	0
Mr. A. J. Hands	...	...	...	2	0	0
Mr. W. J. Harris, M.R.C.S.	...	...	...	5	5	0
Mr. R. Heap, M.A.	...	...	...	10	10	0
Capt. C. M. W. Hepworth	...	...	...	1	1	0
Mr. J. J. Hicks	...	...	...	5	5	0
Mr. J. Hill, M.Inst.C.E.	...	...	...	2	2	0
Mr. H. T. Hodgson, J.P.	...	...	...	2	0	0
Mr. J. Hopkinson, F.G.S.	...	...	...	5	5	0
Mr. H. Horncastle	...	...	...	2	2	0
Mr. W. D. Howard, F.I.C.	...	...	...	10	10	0
Mr. J. Hunter, Assoc.M.Inst.C.E. (in three years)	...	...	...	9	9	0
Lieut.-Col. H. S. Knight, F.R.A.S.	...	...	...	1	1	0
Mr. J. R. Knight	...	...	...	10	10	0
Mr. Baldwin Latham, M.Inst.C.E.	...	...	...	52	10	0
Dr. R. Lawson, F.S.S.	...	...	...	10	0	0
Mr. G. J. Lee, F.R.M.S.	...	...	...	1	1	0
Mr. R. C. Cann Lippincott	...	...	...	1	0	0
Mr. L. W. Longstaff, F.R.G.S.	...	...	...	25	0	0
Capt. J. P. Maclear, R.N., F.R.G.S.	...	...	...	10	10	0
Mr. J. Mansergh, M.Inst.C.E.	...	...	...	10	10	0
Dr. W. Marcet, F.R.S.	...	...	...	50	0	0
Mr. H. J. Marten, M.Inst.C.E.	...	...	...	10	10	0
Admiral T. L. Massie	...	...	...	4	1	0
Mr. E. Mawley, F.R.H.S.	...	...	...	5	5	0
Mr. H. Mellish, J.P.	...	...	...	10	10	0
Dr. J. W. Moore	...	...	...	1	0	0
Mr. R. T. Morgan	...	...	...	1	1	0
Mr. L. P. Muirhead (in three years)	...	...	...	3	3	0
Mr. C. E. Mumford	...	...	...	2	0	0
Mr. R. W. Munro	...	...	...	4	4	0
Messrs. Negretti and Zambra	...	...	...	10	10	0
Mr. T. H. G. Newton, M.A., J.P.	...	...	...	5	0	0
Dr. G. Oliver	...	...	...	5	0	0
Miss E. A. Ormerod	...	...	...	10	10	0
Mr. A. F. Osler, F.R.S.	...	...	...	25	0	0
Rev. J. D. Parker, LL.D.	...	...	...	10	10	0
Mr. J. Parnell, F.R.A.S.	...	...	...	10	10	0
Mr. A. A. Pearson	...	...	...	1	0	0
Mr. C. N. Pearson	...	...	...	1	1	0
Mr. C. E. Peek, M.A., F.R.G.S.	...	...	...	5	0	0
Mr. H. Perigal, F.R.A.S.	...	...	...	10	10	0
Mr. F. H. Phillips	...	...	...	2	0	0
Mr. C. M. Powell	...	...	...	5	0	0
Mr. A. W. Preston	...	...	...	1	1	0
Mr. C. L. Prince, M.R.C.S., F.R.A.S.	...	...	...	3	3	0
Dr. W. T. Radford, F.R.A.S.	...	...	...	10	0	0

Carried forward £774 2 0

						£	s.	d.
	Brought forward	...	...	...	...	774	2	0
Mr. A. Rapkin	...	...	...	...	...	2	2	0
Capt. H. E. Rawson, R.E.	...	...	...	...	...	2	2	0
Mr. T. F. Read (in five years)	...	...	...	...	...	5	5	0
Mr. C. R. Rivington	...	...	...	...	...	5	5	0
Dr. J. Robb	...	...	...	...	...	1	1	0
Mr. J. Rose-Innes, B.A., B.Sc.	...	...	...	...	...	1	10	0
Mr. A. L. Rotch, B.Sc.	...	...	...	...	...	5	0	0
Sir D. L. Salomons, Bart.	...	...	...	...	...	10	0	0
Mr. B. H. Scott, F.R.S. (in two years)	...	...	...	...	...	10	10	0
Mr. S. W. Silver, F.R.G.S.	...	...	...	...	...	10	10	0
Mr. J. G. Single, M.Inst.C.E.	...	...	...	...	...	5	0	0
Dr. F. G. Smart	...	...	...	...	...	10	10	0
Mr. E. J. C. Smith	...	...	...	...	...	0	10	6
Mr. H. Smith	...	...	...	...	...	2	2	0
Mr. R. T. Smith, M.Inst.C.E.	...	...	...	...	...	2	0	0
Mr. H. S. Snell, F.R.I.B.A.	...	...	...	...	...	10	10	0
Mr. H. Southall	...	...	...	...	...	10	10	0
Mr. W. F. Stanley, F.G.S.	...	...	...	...	...	5	0	0
Rev. C. J. Steward, M.A.	...	...	...	...	...	1	0	0
Lieut.-Gen. R. Strachey, R.E., F.R.S.	...	...	...	...	...	10	0	0
Mr. R. F. Sturge	...	...	...	...	...	2	2	0
Mr. G. J. Symons, F.R.S.	...	...	...	...	...	10	10	0
Mr. H. S. Tabor (in three years)	...	...	...	...	...	6	6	0
Rev. C. J. Taylor, F.R.A.S.	...	...	...	...	...	2	2	0
Dr. H. C. Taylor, J.P.	...	...	...	...	...	2	0	0
Mr. E. H. Ryan Tenison, M.R.C.S.	...	...	...	...	...	0	10	6
Mr. S. Tomlinson, Assoc.M.Inst.C.E. (in two years)	...	...	...	...	...	10	10	0
Capt. H. Toynbee, F.R.A.S.	...	...	...	...	...	2	10	0
Dr. J. W. Tripe (in two years)	...	...	...	...	...	10	10	0
Mr. W. B. Tripp, M.Inst.C.E.	...	...	...	...	...	1	1	0
Capt. S. Trott	...	...	...	...	...	10	10	0
Mr. W. H. Tyndall (in two years)	...	...	...	...	...	10	10	0
Mr. R. Tyrer, B.A.	...	...	...	...	...	1	0	0
Mr. B. C. Wainwright	...	...	...	...	...	10	10	0
Mr. H. S. Wallis	...	...	...	...	...	1	1	0
Dr. J. Walther	...	...	...	...	...	2	2	0
Capt. W. Watson	...	...	...	...	...	5	5	0
Mr. B. I. Whitaker, J.P.	...	...	...	...	...	5	5	0
Mr. G. M. Whipple, B.Sc. F.R.A.S.	...	...	...	...	...	2	0	0
Dr. C. T. Williams, M.A.	...	...	...	...	...	100	0	0
Mr. T. Wilson (in two years)	...	...	...	...	...	10	10	0
Mr. E. Woods, M.Inst.C.E.	...	...	...	...	...	10	10	0
Mr. H. Wortham, F.R.A.S.	...	...	...	...	...	2	2	0
Mr. P. Wright, F.C.S.	...	...	...	...	...	5	0	0
Col. W. S. Young	...	...	...	...	...	2	2	0
						<u>£1110 18 0</u>		

APPEN.

STATEMENT OF RECEIPTS AND EXPENDITURE

RECEIPTS.				£	s.	d.	£	s.	d.
Balance from 1889.....							416	5	10
Subscriptions for 1890'.....				671	11	11			
Do. former years				26	4	0			
Do. paid in advance				35	2	0			
Life Compositions				63	0	0			
Entrance Fees				54	0	0			
				<hr/>			849	17	11
Meteorological Office—Copies of Returns.....				120	12	1			
Do. Grant towards Inspection Expenses				25	0	0			
				<hr/>			145	12	1
Dividends on Stock							63	5	0
Sale of Publications							33	0	8
Grant for Thunderstorm Inquiry							30	0	0
New Premises Fund—Contributions of Fellows				750	7	0			
Interest on Investment				4	1	8			
				<hr/>			754	8	3
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DIX II.

FOR THE YEAR ENDING DECEMBER 31st, 1890.

PAYMENTS.

	£ s. d.	£ s. d.
<i>Journal, &c. :—</i>		
Printing, Nos. 73 to 76.....	128 17 6	
Illustrations	21 19 6	
Authors' Copies	13 18 0	
Meteorological Record, Nos. 35 to 38.....	50 1 0	
Registrar-General's Reports	8 8 0	
		223 4 0
<i>Printing, &c. :—</i>		
General Printing	33 0 0	
List of Fellows	9 12 6	
Library Catalogue	248 10 0	
Stationery	18 15 11	
Books and Bookbinding	19 7 9	
		319 6 2
<i>Office Expenses :—</i>		
Salaries	343 0 0	
Rent and Housekeeper	48 7 0	
Furniture, Repairs, Coals, &c.....	23 4 4	
Postage	64 16 1	
Petty Expenses	9 11 2	
Refreshments at Meetings	14 4 0	
Exhibition of Instruments	8 4 7	
		510 7 2
<i>Observations :—</i>		
Inspection of Stations	49 14 2	
Observers at Old Street and Seathwaite	7 2 0	
Instruments	2 5 0	
Thunderstorm Discussion	11 14 0	
		70 15 2
<i>Stock :—</i>		
Purchase of £54 18s. N. S. W. 4 per cent. Stock		63 0 0
<i>New Premises Fund :—</i>		
Investment of Contributions (including Grant by the Society of £50)		766 17 8
		1953 9 9
<i>Balance :—</i>		
At Bank (including £37 11s. balance of New Premises Fund)	319 10 4	
In hands of the Assistant-Secretary	19 9 8	
		339 0 0
		£2292 9 9

Examined and compared with the Vouchers, and found correct,

J. S. HARDING, JUNR., }
H. SOWERBY WALLIS, } *Auditors.*

January 14th, 1891.

APPEN-

ASSETS AND LIABILITIES

LIABILITIES.			£	s.	d.
To Subscriptions paid in advance			35	2	0
„ Grant for Thunderstorm Inquiry, unexpended			26	14	6
„ New Premises Fund			858	8	11
			<hr/>		
			920	5	5
„ Excess ¹ of Assets over Liabilities			2492	0	5

£3412 5 10

¹ This excess is exclusive of the value of the Library and Stock of Publications.

NEW PRE-

<i>Balance :—</i>	£	s.	d.	£	s.	d.
Purchase of £51 5s. 8d. Consols, 1889	50	0	0			
„ £800 0s. 0d. „ 1890	766	17	3			
	<hr/>					
Cash in Bank					816	17 3
					41	11 8

£858 8 11

DIX II.—Continued.

ON JANUARY 1ST, 1891.

ASSETS.			
	£ s. d.	£ s. d.	
By Investment in M. S. and L. R. 4½ Debenture Stock, £800 at 138	1104 0 0		
„ Investment in N. S. W. 4 per cent. Inscribed Stock, £654 18s. at 114½	749 17 2		
„ Investment in 2½ per cent. Consols, £250 at 95½	239 7 6		
„ New Premises Fund.—Investment in 2½ per cent. Con- sols, £851 6s. 8d. at 95½	815 2 0		
		2908 6 8	
„ Subscriptions unpaid, estimated at	25 0 0		
„ Entrance Fees unpaid	5 0 0		
„ Interest on Stock	34 19 2		
		64 19 2	
„ Furniture, Fittings, &c.	35 0 0		
„ Instruments	65 0 0		
		100 0 0	
„ Cash in hands of Bank of England (including £87 11s. balance of New Premises Fund)	819 10 4		
„ Cash in hands of Assistant Secretary	19 9 8		
		339 0 0	
		<u>£3412 5 10</u>	

J. S. HARDING, JUNR., }
H. SOWERBY WALLIS, } *Auditors.*
WILLIAM MARRIOTT, *Assistant Secretary.*

January 14th, 1891.

MISES FUND.

	£ s. d.	£ s. d.
Grant by the Society, 1889	50 0 0	
„ „ „ 1890	50 0 0	
		100 0 0
Contributions of Fellows, 1890		750 7 0
Interest to October 5 th , 1890	4 1 3	
„ January 5 th , 1891	4 0 8	
		8 1 11
		<u>£858 8 11</u>

J. S. HARDING, JUNR., }
H. SOWERBY WALLIS, } *Auditors.*
WILLIAM MARRIOTT, *Assistant Secretary.*

January 14th, 1891.

APPENDIX III.

INSPECTION OF THE STATIONS, 1890.

I have visited all the stations north of Lat. 52°N. which were not inspected last year. The stations, on the whole, were in a very satisfactory condition, the observers taking great interest in the work. As I call upon the observers without previous notice, I am able to see the stations in their normal condition.

These visits are of great service, as the observers do not always notice the growth of trees, &c. in the vicinity of the instruments, and the effect which these may have upon the exposure. The observers also greatly value the visits, as they look upon them as some recognition of their services to the Society.

The changes in the zeros of the thermometers were not so large as those found in the instruments during last year's inspection. The changes were as follows :—

Dry.	Wet.	Max.	Min.	Earth.
4 risen 0 ^o ·1	4 risen 0 ^o ·1	8 risen 0 ^o ·1	5 gone down 0 ^o ·2	1 risen 0 ^o ·3
1 „ 0·2	1 „ 0·2	2 „ 0·3	5 „ 0·3	
1 „ 0·4	1 „ 0·4			

These changes show that the zeros of mercurial thermometers continue to rise, and of spirit thermometers to sink, with age.

The photographs of the stations which have been taken during the present inspection are not so good as those taken last year, the weather at the time of my visits being often wet and unfavourable for photography.

WILLIAM MARRIOTT.

October 15th, 1890.

NOTES ON THE STATIONS.

ASPLEY GUISE, *September 10th*.—The thermometer screen, rain gauge, and solar and grass thermometers were moved in May 1890 some distance east-south-east of the former site, which had become much sheltered by the growth of trees. The minimum thermometer had 0^o·7 of spirit at the top of the tube.

BELPER, *August 15th*.—The thermometer screen is somewhat shaded by a tree. On testing the thermometers it was found that the maximum had gone up 0^o·3, and the wet 0^o·1.

BLACKPOOL, *August 19th*.—This station was not in a satisfactory condition. The acting observer had only been in charge a few months, and had received little or no instruction as to the reading of the instruments, &c. The rain gauge was not properly fixed in the ground. The thermometer screen required painting. The minimum thermometer had been broken the day before my visit. The sunshine recorder, which is placed on the roof of the Pavilion at the end of the Pier, required adjusting, as the trace was not parallel with the lines on the card.

BOLTON, August 18th.—This station was in good order. The anemometer had been mounted on a pole in the meteorological enclosure, and appeared to be working well. The sunshine recorder required to be made a fixture. The dry-bulb had gone up $0^{\circ}1$, and the one foot earth thermometer $0^{\circ}8$.

BURTON-ON-TRENT, August 12th.—The instruments are placed in an enclosure surrounded by iron railings in a field on the south side of St. Paul's Square. The exposure is very open. The rain gauge was too near the thermometer screen, and required to be moved about 8 feet further to the south-west. The muslin on the wet bulb required changing. Mr. Wells has a hollow cylinder bulb grass minimum thermometer which reads 4° lower than when first obtained.

BUXTON, August 15th.—The instruments were in good order. The maximum thermometer, which some months previously had lost its index, was working all right, the index having been set right by the maker.

CHEADLE, August 14th.—This station was in good order. Two trees on the north-east and south-east of the rain gauge are growing up, and will soon make too great an angle with the gauge. The grass minimum thermometer had a little spirit at the top of the tube.

CROMER, July 24th.—I called on Mr. Sandford for the thermometers which had been used by Mr. Cooper. After some conversation Mr. Sandford agreed to continue the observations if a set of instruments were lent by the Society. I selected a fresh site for the thermometer screen, the former site being objected to as being too conspicuous. The rain gauge will be better exposed than formerly.

DRIFFIELD, July 19th.—The instruments are well exposed in a large strawberry garden. The ground is nearly flat, but rises slightly from south to north. The sub-soil is clay on chalk. The station was in good order.

GREAT THURLOW, September 11th.—This station is in the valley of the Stour, four miles north of Haverhill, and ten miles south-south-east of Newmarket. The ground is undulating in the district. The thermometer screen is placed on the lawn of Hill House. The rain gauge is on the lawn of the Hall. The instruments were in good order.

HARROGATE, July 15th.—The instruments were in the same position as formerly, in the private grounds at West End Park. The maximum thermometer had gone up $0^{\circ}1$. Mr. Wilson had procured a new verified set of instruments which were to be placed in the Bog Valley Gardens, where the ground slopes from the north-west to the south-east. A Jordan sunshine recorder will also be put up.

HILLINGTON, July 24th.—The thermometers were all correct except the grass minimum, which had gone down $0^{\circ}8$.

HODSOCK, August 29th.—This station was in good order, and the thermometers all correct.

KENILWORTH, August 12th.—The minimum thermometer had gone down $0^{\circ}8$, otherwise the instruments were in good order.

KIRKLAND, August 23rd.—This station was organised in connection with the Helm Wind Inquiry. Only the dry bulb and the thermograph are in the

screen. The thermograph was not working very satisfactorily. On testing the thermometers it was found that the dry and wet had both gone up $0^{\circ}1$.

LINCOLN, July 22nd.—The electrical thermometer appeared to be working satisfactorily. Two of the zincs in the battery were much worn, and would shortly require to be renewed. The screen for the electrical and check thermometers was to be painted the next time the painters were on the tower. The wet and the check thermometers had both gone up $0^{\circ}1$, and the minimum had gone down $0^{\circ}2$. The rain gauge required a little soldering.

LOWESTOFT, July 25th.—The observations are taken by Mrs. Miller, as Mr. Miller is away the greater part of the year. The minimum thermometer had gone down $0^{\circ}2$. The 1 foot and 2 feet earth thermometers have long tubes enclosed in wooden cases, and could not consequently be compared. The tubes are not graduated.

MACCLESFIELD, August 16th.—The thermometers were all correct except the minimum, which had $0^{\circ}5$ of spirit up the tube. The thermometer screen required repairing and painting.

MALVERN, August 11th.—The thermometer screen is placed in a terraced garden, at the back of Belle Vue Terrace, and at the foot of the Malvern Hills. The rain gauge is on a wall. Considering the surroundings, the exposure of the instruments is fairly good. The dry had gone up $0^{\circ}6$, and the wet $0^{\circ}5$.

NEWTON-BEIGNY, August 22nd.—This station was in good order. The maximum thermometer had gone up $0^{\circ}1$. I could not test the earth thermometers as they had long tubes buried in the soil.

ROTHBURY, July 17th.—I called on Mr. Bertram, the bailiff of Lord Armstrong, with the view of getting a station organised at Cragside. I also saw Lord Armstrong, who agreed to equip a climatological station. I selected a site for the thermometer screen in an open situation. The rain gauge, which had been in use for some years, was in good condition. I visited this place again on August 26th, the day after the thermometer screen had been erected, and the instruments put in position.

ROUNTON, July 16th.—The thermometer screen required painting. The maximum had gone up $0^{\circ}8$, and the grass minimum had gone down $0^{\circ}3$. I instructed the observer as to the management of the wet bulb during frost.

SCALEBY, August 25th.—The wet bulb thermometer was not working correctly. After being properly wetted, the thermometer read $8^{\circ}4$ lower than previously. The minimum thermometer had gone down $0^{\circ}2$.

SCARBOROUGH, July 18th.—The muslin and cotton on the wet bulb were not in working order. The thermometer screen required painting. I recommended that the position of the thermometers in the screen should be rearranged, and also that the currant bushes round the screen should be cut down. On comparing the thermometers, it was found that the wet and the maximum had both gone up $0^{\circ}1$, and that the minimum had gone down $0^{\circ}8$.

SEATHWAITE, August 21st.—This station was in good order. The dry had gone up $0^{\circ}1$. As the index of the Phillips' maximum had got into the bulb, I brought the thermometer away with me, there still being a Negretti maximum left.

SOMERLEYTON, *July 25th*.—All the instruments were in good order except the minimum, which had some spirit at the top of the tube.

SOUTHWELL, *August 28th*.—This station was in good order. On comparing the thermometers it was found that the minimum had gone down $0^{\circ}2$.

SUTTON COLDFIELD, *August 13th*.—The Jordan sunshine recorder is mounted on the turret of the Town Hall, and has a free exposure. Mr. Marston has also a set of instruments in his garden, and takes regular Second Order observations.

TUNBRIDGE WELLS, *December 19th*.—This station is on Mount Ephraim, about the highest part of Tunbridge Wells. The station was in good order. The sunshine recorder is mounted on the south corner of the tower of the house, and has an excellent exposure. On comparing the thermometers it was found that the dry had gone up $0^{\circ}6$ and the wet $0^{\circ}5$.

USHAW, *July 16th*.—This station was in good order.

WAKEFIELD, *July 14th*.—The thermometer screen required painting, and the fastening of the door to be altered. The funnel of the rain gauge needed soldering. The muslin on the wet bulb was dirty.

WINDERMERE, *August 20th*.—The Rev. T. Mackereth has put up his instruments in his yard, which is somewhat confined. He has, however, made the best of the circumstances, and will no doubt get very fair results. On comparing the thermometers it was found that the maximum had gone up $0^{\circ}8$, and that the minimum had gone down $0^{\circ}2$. I also saw the Jordan sunshine recorder, which is mounted on the roof of the Hydropathic Hotel at Bowness; the exposure is very good.

WYDE, *July 23rd*.—I called on Mr. Egar to inquire whether he would equip his station so as to fulfil the Society's requirements. This he agreed to do. I selected a fresh site for the instruments, as the existing one was rather confined. I visited this station again on September 4th, and saw the instruments in their new position. The exposure is very good. On comparing the thermometers it was found that the dry and wet had both gone up $0^{\circ}2$.

APPENDIX IV.

OBITUARY NOTICES.

DR. CHRISTOPHER HENRY DIDERICUS BUYS BALLOT, who died February 8rd, 1890, in the 78rd year of his age, was born at Kloetingen, where his father was a Pastor in the Reformed Church of Holland. He went to the University of Utrecht at the age of 18, and took out his Doctor's Degree in 1844. His thesis was *de Synaphia et Prosaphia*. Next year he was appointed "Docent" in Mineralogy and Geology, soon after Professor of Mathematics, and subsequently Professor of Experimental Physics, a post which he held till 1887, when, according to the Dutch law, he had to retire after 40 years' service in the chair.

As to his lectures they were full of new ideas, many of them far in advance:

of his age. One of his earliest pamphlets bore the title, *A Sketch of the Physiology of Inorganic Nature*, a sufficiently startling paradox! Many of the ideas put forward by Buys Ballot in the first half of this century are now being adopted as scientific truths on the authorities of Maxwell and Clausius.

His connection with Meteorology began in 1849. He fitted up at his own expense a cellar in the Sonnenborgh, at Utrecht, for magnetic observations, and started meteorological observations above ground at the same place. The observations were made by Kreeke, but discussed and published by Buys Ballot. In 1854 the establishment was taken over by the Government, and became the Royal Meteorological Institute of Utrecht. The "Law," by which he is most generally known, was popularly explained by him in the pamphlet *Eenige Regelen vom Aanstaande Weersveranderingen in Nederland, &c.*, published in 1860, which was translated by Adriani and published in England in 1868. It was Mr. Joseph Baxendell and Mr. G. V. Vernon, of Manchester, who at last, in 1867, obtained official recognition of this principle in England.

Buys Ballot in most of his investigations dealt exclusively with the variations from the mean values of the meteorological elements for each station. This enabled him to dispense with the reduction of the barometer to sea level, but this mode of treatment of observations has not met with general acceptance.

He was from the first deeply interested in Meteorological Congress work, and in international co-operation in investigations, and was an ardent advocate of the visionary scheme of an International Institute, which was broached at Vienna and at Rome.

He has left behind him the memory of one of the most modest, simple-minded and amiable of men, while the long list of his papers (41 prior to 1875 in the Royal Society Catalogue) attests his industry and marvellous ability.

He was elected an Honorary Member of the Society on June 17th, 1874.

CHARLES OCTAVUS BUDD was the eighth son of Samuel Budd, a medical practitioner at North Tawton, in Devonshire, and was born at North Tawton in the month of July 1822. He entered at Pembroke College, Cambridge, in 1840, and graduated B.A. in 1844, when he was 8rd Wrangler. Shortly afterwards he was elected a Fellow of his college, and being a bachelor he retained his fellowship up to the time of his death, which occurred at Torquay on the 24th December 1890.

He belonged to a family well known in the medical profession, in which several of his brothers attained high distinction: two, the late Dr. Geo. Budd, formerly Professor of Medicine in King's College, London, and the late Dr. William Budd of Bristol, both being Fellows of the Royal Society, and deemed worthy of a place in the *Dictionary of National Biography*. In consequence of ill-health Mr. C. O. Budd was never able to follow any profession, but he was known to his friends as a man of conspicuous ability and great general culture.

He was elected a Fellow of the Society on April 16th, 1873.

SAMUEL ALEXANDER HILL was the eldest son of a clergyman residing at Ballyboley, near Belfast, in the county of Antrim, and was born at that place in 1851. He received his early education in a local school, and afterwards studied in the Training School at Dublin, where he greatly distinguished himself, especially in the science classes, and gained a scholarship which enabled him to matriculate at the Royal School of Mines, and also in the London University. Having completed his three years' course in the former institution, and taken the degree of Bachelor of Science, he was offered the Professorship of Physical Science in the Muir College, Allahabad, and in 1875 he proceeded to India to take up the appointment. On his arrival he was appointed also Meteorological Reporter to the Government of the North-west Provinces, and he continued to hold these appointments conjointly up to the time of his death.

A professorship in an Indian college does not as a rule afford many facilities for original scientific research, and the climate of the Gangetic Plain is but little favourable to mental exertion, but Mr. Hill was not one of those who content themselves with discharging the merely administrative duties of their appointments, and inasmuch as his Meteorological Reportership placed at his command the data furnished by the province he so ably superintended, he speedily devoted himself to the study and discussion of these data, a task for which his knowledge of physics and mathematics peculiarly fitted him. A subject which early engaged his attention was the detection of variations in the intensity of the solar heat by means of the black-bulb thermometer *in vacuo*, and by selecting for comparison those registers only which recorded the readings of one and the same instrument, always exposed on the same spot, and applying certain corrections for the varying conditions of the atmosphere in respect of humidity, suspended dust, &c., he succeeded in demonstrating a very well-marked oscillation of the insolation temperature, having its minimum coincident with the epoch of maximum sun-spots, and *vice-versâ*. A similar oscillation has since been shown to affect the temperature of the Indian atmosphere as a whole. Two of Mr. Hill's papers on the above subject were published in the *Proceedings of the Royal Society* in 1881 and 1882, and three others in the *Journal of the Asiatic Society of Bengal* in 1883, 1884, and 1886.

Most of his more important writings were published in the *Indian Meteorological Memoirs* and the *Philosophical Transactions* of the Royal Society. The former include a very complete discussion of the climate of Allahabad, a memoir on the meteorology of the N.W. Himalaya, another on the rainfall of Benares in relation to the prevailing winds, and one on the distribution of temperature in North-western India, illustrated by monthly and annual isothermal charts of the greater part of Northern India; furthermore, two memoirs on the vertical distribution of temperature and humidity in the lowest layer of the atmosphere, and one on the temperature of the ground at small depths below the surface, and its variations from year to year.

To the *Philosophical Transactions* of 1887 he contributed a memoir on certain anomalies in the winds of Northern India, which he traced to the dis-

tribution of pressure at an elevation of 10,000 ft. above the sea level, and showed that this is entirely different in character from that given by observations on the plains. Several of his minor contributions appeared in *Nature* and the *Zeitschrift* of the Austrian Meteorological Society, and one, viz. a Criticism of Professor Langley's researches on solar heat, in the *Quarterly Journal* of this Society, of which Mr. Hill was elected a Fellow in February 1884.

Mr. Hill's treatment of the many subjects he has discussed displays much originality of conception and method, combined with strict adherence to the canons of logical reasoning, and he has contributed in no small degree to the advancement of our knowledge of Indian meteorology and incidentally to that of meteorological processes in general. Up to the day before his death there seemed no reason for misgiving that he might not continue for many years to come to add to the good work he had already accomplished. About the middle of September last he had indeed a smart attack of fever, such as is not unusual at that unhealthy season, but he appeared to be almost convalescent when, without any warning, congestion of the brain set in, and after 18 hours of unconsciousness he passed away quietly on the morning of the 28rd at the age of 88 years and 11 months.

PICKERING PHIPPS, who was formerly Conservative Member of Parliament for the Borough of Northampton, and afterwards for South Northamptonshire, died at his residence, Collingtree, Northamptonshire, on Sunday, September 7th, aged 68. Mr. Phipps was the senior partner in the firm of Phipps and Son, Brewers, Northampton and Towcester. He was a member of the Northampton Town Council for 80 years, and was twice elected mayor of the borough.

He was elected a Fellow of this Society on January 15th, 1879.

SIR WARINGTON W. SMYTH was the eldest son of Admiral W. H. Smyth, F.R.S., and was born at Naples in 1817. He was educated at Westminster and Bedford Schools, and at Trinity College, Cambridge, where he was one of the winning University crew on the Thames in 1839. In that year he graduated and obtained a travelling Fellowship, which enabled him to devote more than four years to a journey through the chief mining districts of Europe, and thus to lay the foundation of that practical knowledge which subsequently made him the greatest British authority on mining matters. As a result of his travels through the European and Asiatic dominions of the Sultan, he published in 1854 a work entitled *A Year with the Turks*. His official career began in 1844, when he was appointed by Sir Henry de la Beche to a post on the Geological Survey, and while holding this position he explored and geologically mapped various metalliferous districts. In 1845 he joined the Geological Society, and in 1866 was elected its President. For the last 17 years he acted as Foreign Secretary, in which post his rare linguistic powers proved of great service to the Society. On the foundation of the Royal School of Mines in 1851, he was appointed the first Lecturer on Mining and Mineralogy. On the reorganisation of the School in 1881 he gave up

the chair of Mineralogy, but acted as Professor of Mining until his death. He held the office of Inspector of the Mines in the Duchy of Cornwall, and in 1857 he was also appointed Comptroller of all the mineral properties belonging to the Crown.

In 1879 a Royal Commission was appointed to inquire into accidents in mines, and the possible means of preventing their occurrence, and of limiting their disastrous consequences. Prof. Smyth was appointed chairman. The Commission ended its work in 1886, and the Report definitely settled some important questions bearing upon the diminution of accidents in mines.

To his scientific attainments Sir Warington added singular literary skill. His early classical training enabled him to write with rare elegance and vigour. As a teacher he was very popular with his pupils, his success as a lecturer being due not only to his finished delivery, but also to his skill as a draughtsman, which enabled him to dispense with the aid of elaborate diagrams, and to rely merely on accurate blackboard sketches, which he drew with great rapidity in the presence of his class. His reputation as Professor attracted to the School of Mines students from all parts of the world.

For his labours on the Accidents in Mines Commission and for his other public services he received the honour of knighthood on the occasion of Her Majesty's Jubilee. Throughout his life he refused the great pecuniary rewards offered by the commercial branches of mining, and preferred to devote the half-century during which he was engaged in business connected with mines to the service of science and of the State. Although he had been in ill-health for some time he never neglected his official duties. He died in harness, with a partially corrected examination paper on the table before him, on June 29th.

He was elected a Fellow of this Society on March 25th, 1856.

ADMIRAL SIR BARTHOLOMEW JAMES SULLIVAN was the eldest son of the late Rear-Admiral Ball Sullivan, and was born in 1810. He entered the service in 1823, and became Lieutenant in 1830. In 1841 he was promoted to the position of Commander for surveying services. He was surveying officer to the combined Paraná Expedition, from September 1845 to April 1846, at Obligado; made the plan for the attack and commanded the leading division of ships and the advance of the landing force. For this service he was promoted to Captain in 1845.

In 1848, as "Colonel and Chief of the Staff," he organised the Dockyard Volunteers. He was Surveying Captain of the Baltic Fleet throughout the war; was gazetted for services at Bomarsund in 1854, and Sveaborg in 1855; proposed, planned, and carried out under Rear-Admiral the Hon. R. S. Dundas the bombardment of Sveaborg, and obtained the Baltic medal. In 1868 he became Rear-Admiral, in 1870 Vice-Admiral, and in 1877 Admiral.

Sir B. J. Sullivan was made a C.B. in 1855 and K.C.B. in 1869. He was naval officer of the Marine Department, Board of Trade, from December 1856 to April 1865. He died at Bournemouth on New Year's Day, 1890.

He was elected a Fellow of this Society on March 16th, 1882.

APPENDIX V.

BOOKS PURCHASED DURING THE YEAR 1890.

BIGOT DE MORGUES, P.M.S.—Mémoire historique et physique sur les chutes des pierres tombées sur la surface de la terre à diverses époques. 8vo. (1812.)

COULVIER-GRAVIER and SAIGEV.—Recherches sur les étoiles filantes. Introduction historique. 8vo. (1847.)

COUSTÉ, —.—Théorie physico-dynamique des météores à tourbillons suivie d'un appendice sur "la défense de la loi des tempêtes" de M. Faye. 8vo. (1875.)

[DEFOE, D.]—The Storm: or, a collection of the most remarkable casualties and disasters which happen'd in the late dreadful tempest, both by sea and land. 8vo. (1704.)

DUFOUR, L.—Notes sur le problème de la variation du climat. 8vo. (1870.)

FOURNET, J.—Note sur le froid périodique du mois de Mai. 8vo. (1848.)

GRANDSAGNE, A. de, and L. FOUCHÉ.—Manuel complet de physique et de météorologie. 2 éd. 12mo. (1885.)

HILDEBRANDSSON, H. H., W. KÖPPEN, and G. NEUMAYER. Wolken-Atlas. 4to. (1890.)

MACKENZIE, G.—The system of the weather of the British Islands. 8vo. (1821.)

MEDICAL ESSAYS AND OBSERVATIONS published by a Society in Edinburgh. 4th ed. 5 vols. 12mo. (1752.)

NJINÉ TAGUILSK (RUSSIA).—Observations météorologiques faites à Nijné-Taguilsk (Monts Oural), du 1er October 1889 au 31 Décembre 1890. 8vo. (1890.)

OFFICIAL YEAR BOOK OF THE SCIENTIFIC AND LEARNED SOCIETIES OF Great Britain and Ireland. 1890. 8vo. (1890.)

PARIS, MINISTÈRE DU COMMERCE, DE L'INDUSTRIE ET DES COLONIES.—Exposition Universelle Internationale de 1889. Direction générale de l'Exploitation. Congrès Météorologique International tenu à Paris du 19 au 26 Septembre 1889. Procès-verbaux, sommaires. Par MM. Moureaux, Lasne, l'Abbé Maze. 8vo. (1889.)

PARIS, SOCIÉTÉ MÉTÉOROLOGIQUE DE FRANCE.—Congrès Météorologique International tenu à Paris du 19 au 26 Septembre 1889. Mémoires. 8vo. (n.d.)

REINZER, F.—Meteorologia Philosophico-Politica, in duodecim dissertationes per questiones meteorologicas, et conclusiones politicas divisa, appositisque symbolis illustrata. Folio. (1709.)

APPENDIX VI.

DONATIONS RECEIVED DURING THE YEAR 1890.

Presented by Societies, Institutions, &c.

ADELAIDE, GOVERNMENT OBSERVATORY.—Rainfall in South Australia, 1887.—Report on telegraphic determination of Australian longitudes.

ALLAHABAD, METEOROLOGICAL OFFICE.—Annual statement of rainfall in the North-Western Provinces and Oudh, 1889.

BAYONNE, SOCIÉTÉ DE CLIMATOLOGIE PYRÉNÉENNE.—Bulletin, 2me Année, Nos. 10 to 3e Année, No. 9.

BERLIN, DEUTSCHE METEOROLOGISCHE GESELLSCHAFT.—Meteorologische Zeitschrift, 1890.

BERLIN, GESELLSCHAFT FÜR ERDKUNDE.—Verhandlungen, Band XVI., No: 10 to Band XVII., No. 9.—Zeitschrift, Nos. 143 to 149.

BERLIN, KÖNIGLICH PREUSSISCHES METEOROLOGISCHES INSTITUT.—Ergebnisse der meteorologischen Beobachtungen im Jahre 1889, Heft 2.

BIRKENHEAD, LIVERPOOL OBSERVATORY.—Report of the Astronomer to the Marine Committee, Mersey Docks and Harbour Board, and results of meteorological observations made at the Observatory, 1884-8.

BOMBAY, METEOROLOGICAL OFFICE.—Brief Sketch of the Meteorology of the Bombay Presidency, in 1888-90.

BRISBANE, CHIEF WEATHER BUREAU.—Brisbane Observatory: Meteorological Synopsis, July 1889.—Daily Weather Charts of Australia, July 25th, 1889, to April 8th, 1890.—Summaries of Rainfall in Queensland, July to Dec. 1889.—The Queensland Meteorological Record, July to Sept. 1889.

BRISBANE, GENERAL REGISTER OFFICE.—Report on the Vital Statistics, Oct. 1889 to Sept. 1890.—Queensland Vital Statistics, 1889.

BRUSSELS, INSTITUT NATIONAL DE GÉOGRAPHIE.—Bulletin Météorologique, March 1887, and Dec. 1889 to Nov. 1890.

BRUSSELS, OBSERVATOIRE ROYAL.—Annales Astronomiques, Nouvelle Série, Tome VI.—Annales Météorologiques, Deuxième série, Tome II.—Annuaire 1890.—Bibliographie Générale de l'Astronomie. Par J. C. Houzeau et A. Lancaster. Tome 1. Part 1.

BUDAPEST, K. UNG. CENTRAL-ANSTALT FÜR METEOROLOGIE UND ERDMAGNETISMUS.—Jahrbuch 1887.

CAIRO, SOCIÉTÉ KHÉDIVIALE DE GÉOGRAPHIE.—Sommaire Historique des Travaux Géographiques exécutés en Egypt sous la Dynastie de Mohammed Aly.

CALCUTTA, METEOROLOGICAL OFFICE.—Cyclone Memoirs, Part 2. Bay of Bengal Cyclone, August 21-28, 1888.—Handbook of cyclonic storms in the Bay of Bengal, by J. Eliot.—India Daily Weather Reports, Dec. 8, 1889, to Nov. 16, 1890, and Nov. 24 to Dec. 7, 1890.—Memorandum on the snowfall in the mountain districts of Northern India and Afghanistan, and the abnormal features of the meteorology of India during Jan. to May 1890.—Report on the administration of the Meteorological Department of the Government of India in 1888-89.—Report on the Meteorology of India in 1888.

CALCUTTA, ST. XAVIER'S COLLEGE OBSERVATORY.—Meteorological Observations, July to Dec. 1889.

CAMBRIDGE, HARVARD COLLEGE OBSERVATORY.—Henry Draper Memorial. Second Annual Report of the photographic study of Stellar Spectra.

CAMBRIDGE, NEW ENGLAND METEOROLOGICAL SOCIETY.—Bulletin, Dec. 1889 to Nov. 1890.

CAPE TOWN, METEOROLOGICAL COMMISSION.—Report, 1889.

CHEMNITZ, KÖNIGL. SÄCHSISCHES METEOROLOGISCHES INSTITUT.—Jahrbuch, 1888.

CHRISTIANIA, EDITING COMMITTEE NORWEGIAN NORTH ATLANTIC EXPEDITION 1876-1878.—Zoology. Actinida. By D. C. Danielssen.

CHRISTIANIA, NORSKE METEOROLOGISKE INSTITUT.—Jahrbuch, 1888.

COPENHAGEN, DANSKE METEOROLOGISKE INSTITUT.—Bulletin Météorologique du Nord, Dec. 1889 to Nov. 1890.—Meteorologisk Aarbog, 1885, Pt. 2.

CORDOBA, ACADEMIA NACIONAL DE CIENCIAS.—Boletín, Tomo X. Ent. 3.

CORDOBA, OFICINA METEOROLOGICA ARGENTINA.—Anales, Tomo VII.

CRACOW, K. K. STERNWART.—Meteorologische Beobachtungen, Nov. 1889 to Aug. 1890.

CROYDON, MICROSCOPICAL AND NATURAL HISTORY CLUB.—Daily Rainfall in the Croydon District, Dec. 1889 to Nov. 1890.—Proceedings and Transactions, Feb. 1888 to Jan. 1889.—Report of the Meteorological Sub-Committee for 1889.

DORPAT, OBSERVATORIUM.—Fortsetzung der neuen Untersuchungen über die Bessel'sche Formel und deren Verwendung in der Meteorologie. Von Dr. K. Weihrauch.—Meteorologische Beobachtungen, 1881-3 and 1889.

DUBLIN, GENERAL REGISTER OFFICE.—Annual Report of the Registrar-General (Ireland) 1889.—Weekly Returns of Births and Deaths, Vol. XXVI. No. 52 to Vol. XXVII. No. 51.

DUBLIN, ROYAL DUBLIN SOCIETY.—Scientific Proceedings, Vol. VI. New Series, Pts. 7-9.

DUBLIN, ROYAL IRISH ACADEMY.—"Cunningham Memoirs," No. 5. The Red Stars: observations and catalogue.—Proceedings. Third Series, Vol. I. Nos. 2 to 8.—Transactions, Vol. XXIX. Pts. 12 and 18.

DURBAN, NATAL HARBOUR BOARD.—Chairman's Minute and Departmental Reports for the year 1889.

EDINBURGH, FISHERY BOARD FOR SCOTLAND.—Annual Report, 1889.

EDINBURGH, GENERAL REGISTER OFFICE.—Quarterly Returns of the Births, Marriages and Deaths, registered in Scotland for the four quarters ending Sept. 30, 1890.

EDINBURGH, ROYAL SCOTTISH GEOGRAPHICAL SOCIETY.—Scottish Geographical Magazine, 1890.

EDINBURGH, ROYAL SOCIETY.—Proceedings, Vols. XV. and XVI. 1887-9.

FIUME, I. R. ACCADEMIA DI MARINA.—Meteorological Observations, Nov. 1889 to July 1890.

GENEVA, SOCIÉTÉ DE GÉOGRAPHIE.—Le Globe, 5me. Serie, Tome I.

GLASGOW, PHILOSOPHICAL SOCIETY.—Proceedings. Vol. XXI. 1889-90.

GREENWICH, ROYAL OBSERVATORY.—Areas of faculae and sun-spots, compared with diurnal ranges of magnetic declination, horizontal force, and vertical force, as observed at the Royal Observatory, Greenwich, 1873-88.—Mean daily area of sun-spots for each degree of solar latitude for each year from 1874-1888, as measured on photographs at the Royal Observatory, Greenwich.—Reduction of Meteorological observations, Pt. II.

Barometer, 1874-6, and Thermometers, 1869-76.—Report of the Astronomer Royal to the Board of Visitors, 1890.—Results of Magnetical and Meteorological Observations, 1887.

GUERNSEY, SOCIETY OF NATURAL SCIENCE.—Report and Transactions, 1889.

HALLE, K. LEOP.-CAROL. DEUTSCHE AKADEMIE.—Leopoldina, Heft 25, 1889.—Ueber die Periodicität der Sonnenflecken seit dem Jahre 1618. Von Dr. G. Spoerer.

HAMBURG, DEUTSCHE SEEWART.—Aus dem Archiv, 1889.—Deutsche Ueberseeische meteorologische Beobachtungen, Heft III.—Ergebnisse der meteorologischen Beobachtungen an Stationen in Deutschland, 1888.—Monatsbericht, June 1889 to May 1890.—Wetterbericht, 1890.

HOBART, OBSERVATORY.—Tasmania Rainfall, 1889.

KARLSRUHE, CENTRALBUREAU FÜR METEOROLOGIE UND HYDROGRAPHIE IM GROSHERZOGTHUM BADEN.—Die Ergebnisse der meteorologischen Beobachtungen im Jahre 1889.

KEW OBSERVATORY.—Report of the Kew Committee for the year ending Oct. 31, 1889.

LEON, ESCUELA DE INSTRUCCION SECUNDARIA.—Resumen General de las observaciones meteorologicas, 1889.

LISBON, OBSERVATORIO DO INFANTE D. LUIZ.—Annaes, Vol. XXV. 1887.

LISBON, SOCIEDADE DE GEOGRAPHIA.—Boletim, 8a Serie, Nos. 7, 8, 11, 12; 9a Serie, Nos. 1-6.—Catalogos e Indices. As Publicações.—Indices e Catalogos. A Bibliothica. I. Orbas impressas.

LIVERPOOL, LITERARY AND PHILOSOPHICAL SOCIETY.—Proceedings, Vols. 41-43, 1887-9.

LONDON, BRITISH ASSOCIATION.—Index to Reports and Transactions, 1831-60.—Report, 1889.

LONDON, COLONIAL OFFICE.—Annual Report of the Director of the Royal Alfred Observatory, Mauritius, 1888.—Meteorological Report, Straits Settlements, 1889.—Report of the Director of the Hong Kong Observatory, 1889.

LONDON, GENERAL REGISTER OFFICE.—Annual Summary of Births, Deaths and causes of Death in London and other great towns, 1889.—Quarterly Returns of Births, Marriages and Deaths for the four quarters ending Sept. 30, 1890.—Weekly Returns of Births and Deaths, Vol. L., No. 52, to Vol. LI., No. 51.

LONDON, GEOLOGICAL SOCIETY.—Quarterly Journal, Nos. 181 to 184.

LONDON, INSTITUTE OF CHEMISTRY OF GREAT BRITAIN AND IRELAND.—Register of Fellows and Associates for 1890.

LONDON, INSTITUTION OF ELECTRICAL ENGINEERS.—Journal, Nos. 82 to 89.

LONDON, JUNIOR ENGINEERING SOCIETY.—Programme, &c. Tenth Session, 1890-1.

LONDON, METEOROLOGICAL OFFICE.—Daily Weather Reports, 1890.—Meteorological Observations at stations of the Second Order for the year 1886.—Meteorological Observations at the Foreign and Colonial Stations of the Royal Engineers and the Army Medical Department, 1852-86.—Meteorological Observations made at Sanchez (Samaná Bay), St. Domingo, 1886-8, by the late Dr. W. Reid.—Quarterly Weather Report, 1880, Pt. 2.—Report of the Meteorological Council to the Royal Society for the year ending March 31st, 1889.—Weekly Weather Report, Vol. VI., No. 51, to Vol. VII., No. 51.—Meteorological Observations at Southport, Mar. 30, 1889, to Jan. 3, 1890.—Annual Report of the Botanical Department, Trinidad, 1888.—Report on the Meteorology of Ceylon for 1889.—Bulletin quotidien de l'Algérie, Nov. 1, 1889, to Nov. 30, 1890.—Service Central Météorologique de l'Algérie. Bulletin Mensuel, May 1888 to Feb. 1889.—Annual Report of the Royal Cornwall Polytechnic Society, 1889.—Papers and Proceedings of the Royal Society of Tasmania, 1889.—Anemometer Comparisons.—Cloud Formation.—Determination of "prevailing wind direction."—Pressure and Temperature in low and high.—Storms and a central ascending current.—The relation between wind velocity and pressure.—Tornadoes. All by H. A. Hazen.—Instructions to voluntary observers of the Signal Service, U.S.A.—Barometerstanden en Winden in der Golf van Aden en den Indischen Oceaan bij Kapp Guardafui.—74 Jahresbericht der Naturforschenden Gesellschaft in Emden pro 1888-9.—Expériences de flottage sur les courants superficiels de l'Atlantique Nord. Par le Prince Albert de Monaco.—Sur les causes de l'électricité atmosphérique et terrestre. Par A. C. Becquerel.

LONDON, PHYSICAL SOCIETY.—Proceedings, Vol. X. Pts. 3 and 4.

LONDON, ROYAL AGRICULTURAL SOCIETY OF ENGLAND.—Journal, Third Series, Vol. I. Nos. 1 to 8.—General Index to the Journal, 1865-89.

LONDON, ROYAL ASTRONOMICAL SOCIETY.—Memoirs, Vol. 49, Pt. 2.—Monthly Notices, Vol. L. No. 2 to Vol. LI. No. 1.

LONDON, ROYAL BOTANIC SOCIETY.—Quarterly Record, Nos. 40 to 42.

LONDON, ROYAL INSTITUTION OF GREAT BRITAIN.—Proceedings, No. 83.

LONDON, ROYAL SOCIETY.—Proceedings, Nos. 284 to 294.

LONDON, SANITARY INSTITUTE OF GREAT BRITAIN.—Transactions, Vol. X.—Annual Reports of the Registrar-General, England, 1839-42, 1844-5, 1847-55.—Army Medical Department Reports, 1872, 1878, and 1883.—Descriptive Guide to Bournemouth,—

- Dover as a health resort. By Dr. C. Parsons.—Hamam R'irha, Algiers, a winter health resort. By Dr. G. H. Brandt.—New Zealand Meteorological Report, 1877.—Return of the Average Annual Proportion of Deaths, 1861-70.—Royat, its Mineral Waters and Climate. By Dr. G. H. Brandt.—Scarborough as a health resort. By A. Haviland.
- LONDON, SOCIETY OF ARTS.—Journal, 1890.
- MADRID, OBSERVATORIO.—Observaciones Meteorológicas, 1888-9.—Resumen de las observaciones meteorológicas efectuadas en la Península, 1886.
- MADRID, SOCIEDAD GEOGRAPHICA.—Boletín, Tomo XXVII. No. 4, to Tomo XXIX. No. 4.
- MAGDEBURG, WETTERWARTHE DER MAGDEBURGISCHEN ZEITUNG.—Jahrbuch der meteorologischen Beobachtungen, 1889.
- MANCHESTER, LITERARY AND PHILOSOPHICAL SOCIETY.—Memoirs and Proceedings, Fourth Series, Vol. III.
- MANILA, OBSERVATORIO METEOROLÓGICO.—Curvas Meteorográficas, 1888.—Observaciones Magnéticas, 1888.—Observaciones verificadas, Jan. to Mar. 1890.
- MARLBOROUGH COLLEGE, NATURAL HISTORY SOCIETY.—Report, 1889.
- MARSEILLE, COMMISSION DE MÉTÉOROLOGIE DU DÉPARTEMENT DES BOUCHES-DU-RHONNE.—Bulletin Annuel, 1888.
- MELBOURNE, GOVERNMENT OBSERVATORY.—Monthly Record of results of observations in Meteorology, Terrestrial Magnetism, &c. Aug. 1889 to June 1890.
- MEXICO, OBSERVATORIO ASTRONÓMICO NACIONAL DE TACUBAYA.—Anuario, 1890.
- MEXICO, OBSERVATORIO METEOROLÓGICO MAGNETICO CENTRAL.—Boletín Mensual, Tomo II. Nos. 2 to 12.
- MEXICO, SOCIEDAD CIENTIFICA "ANTONIO ALZATE."—Memorias, Tomo II. No. 12, to Tomo IV. No. 2.
- MICHIGAN, STATE BOARD OF HEALTH.—Comparison of averages of tri-daily, and bi-daily meteorological Observations made at four stations in Michigan during 1889 (MS.).—Principal Meteorological Conditions in Michigan in 1888.—Proceedings and Addresses at a Sanitary Convention at Pontiac, Michigan, Oct. 1889.—Proceedings and Addresses at a Sanitary Convention held at Vicksburg, Michigan, Dec. 5 and 6, 1889.
- MILAN, R. OBSERVATORIO ASTRONOMICÓ DI BRESCIA.—Osservazioni Meteorologiche, 1889.
- MONTEVIDEO, OBSERVATORIO METEOROLÓGICO DEL COLEGIO PIO DE VILLA COLON.—Boletín Mensual, Dec. 1889, and Feb. and Mar. 1890.
- MONTREAL, GEOLOGICAL AND NATURAL HISTORY SURVEY OF CANADA.—Annual Report, New Series, Vol. III., 1887-8.
- MOSCOW, SOCIÉTÉ IMPÉRIALE DES NATURALISTES.—Bulletin, 1889, No. 3, to 1890, No. 2.—Meteorologische Beobachtungen, 1889.
- MUNICH, K. B. METEOROLOGISCHE CENTRAL-STATION.—Beobachtungen der meteorologischen Stationen im Kön. Bayern, Jahrgang XI., Heft 3, to Jahrgang XII., Heft 2.—Uebersicht über die Witterungsverhältnisse im Kön. Bayern, Dec. 1889 to Oct. 1890.
- MUNICH, K. STERNWARTHE.—Meteorologische Beobachtungen im Jahre 1888 and 1889.
- NATAL OBSERVATORY.—Report of the Superintendent, 1889.
- NEWHAVEN, ASTRONOMICAL OBSERVATORY OF YALE UNIVERSITY.—Report 1889 to 1890.—Transactions, Vol. I., pt. 2.
- NEW YORK, ACADEMY OF SCIENCES.—Transactions, Vol. VIII., No. 5, to Vol. IX. No. 2.
- NEW YORK, CENTRAL PARK OBSERVATORY.—Abstracts of Registers from self-recording Instruments, Dec. 1889 to Nov. 1890.
- OXFORD, RADCLIFFE OBSERVATORY.—Results of Meteorological Observations, 1886.
- PARIS, BUREAU CENTRAL MÉTÉOROLOGIQUE DE FRANCE.—Annales, 1885, Part 2; 1886, Part 2; 1887, Parts 1-3.—Bulletin International, 1890.—Rapport du Comité Météorologique International. Réunion de Zurich, 1888.
- PARIS, OBSERVATOIRE MUNICIPAL DE MONTBOURIS.—Annuaire, 1890.
- PARIS, SOCIÉTÉ MÉTÉOROLOGIQUE DE FRANCE.—Annuaire, Sept. 1889 to Sept. 1890.
- PERPIGNAN, OBSERVATOIRE MÉTÉOROLOGIQUE.—Bulletin Météorologique du département des Pyrénées Orientales, 1888-4, and 1886 to 1889.—Description de l'Observatoire.
- PHILADELPHIA, AMERICAN PHILOSOPHICAL SOCIETY.—Proceedings, Nos. 130 to 183.—Transactions, Vol. XVI., New Series, Part 3.
- POLA, K. K. HYDROGRAPHISCHES AMT.—Meteorologische und magnetische Beobachtungen, Nov. 1889 to Oct. 1890.
- POMPEI, LE ARMONIE DELLA RELIGIONE E DELLA CIVILTÀ.—Programma delle Feste di Maggio, 1890.
- PRAGUE, K. K. STERNWARTHE.—Magnetische und meteorologische Beobachtungen, 1889.
- PUEBLA, OBSERVATORIO METEOROLÓGICO DEL COLEGIO DEL ESTADO.—Resumen Correspondiente a cada día, Nov. 1889 to Aug. 1890.
- RIO DE JANEIRO, OBSERVATOIRE.—Annales, Tome IV., Parts 1 and 2.—Anuario, 1888-90.—Revista do Observatorio, Dec. 1889 to Nov. 1890.
- RIO DE JANEIRO, 1º OBSERVATORIO METEOROLÓGICO DA REPARTIÇÃO DOS TELEGRAPHOS DO BRAZIL.—Boletín Mensaes, Vol. III., 1888.

SAN FERNANDO, INSTITUTO Y OBSERVATORIO DE MARINA.—*Anales. Sección 2a. Observaciones Meteorológicas*, 1889.—Catálogo de la Biblioteca.

SAN JOSÉ, INSTITUTO FÍSICO-GEográfico NACIONAL.—*Anales*, 1889. Tome II. 1a Parte.

SAN PAULO, COMMISSAO GEOGRAPHICA E GEOLOGICA.—*Boletim*, Nos. 1 to 3.

SAN SALVADOR, INSTITUTO NACIONAL.—*Observaciones Meteorológicas*, Jan. 1889 to Feb. 1890.

SANTIAGO, OBSERVATORIO ASTRONÓMICO.—*Observaciones Meteorológicas*, 1885-7.

ST. PETERSBURG, K. AKADEMIE DER WISSENSCHAFTEN.—*Repertorium für Meteorologie*. Vols. 12 and 13.

ST. PETERSBURG, PHYSIKALISCHES CENTRAL OBSERVATORIUM.—*Annalen*, 1888; and 1889, Pt. 1.

SYDNEY, GOVERNMENT OBSERVATORY.—*Daily Weather Charts of Australia and New Zealand*, Nov. 1889 to July and Sept. 1890.—*Meteorological Observations*, Jan. to July 1890.—*Results of Meteorological Observations made in New South Wales during 1888*.—*Results of Rain, River and Evaporation Observations made in New South Wales during 1889*.

SYDNEY, ROYAL SOCIETY OF NEW SOUTH WALES.—*Catalogue of the Scientific Books in the Library of the Royal Society of New South Wales*, Pt. 1.—*Journal and Proceedings*, Vol. XXIII. 1889.

TIFLIS, PHYSIKALISCHES OBSERVATORIUM.—*Meteorologische Beobachtungen*, 1887-8.

TOKIO, IMPERIAL UNIVERSITY OF JAPAN.—*Calendar*, 1889-90.

TOKIO, METEOROLOGICAL CENTRAL OBSERVATORY.—*Annual Meteorological Report*, 1887, Pt. 2; 1888, Pt. 1.—*Meteorological Observations at 31 stations in Japan*, 1888.—*Monthly Summaries and Monthly Means*, 1887-8.

TONGA, PREMIER'S OFFICE.—*Statistics of the Tonga Islands*, 1889.

TORONTO, METEOROLOGICAL OFFICE.—*Monthly Weather Review*, Oct. 1889 to Aug. 1890.—*Report of the Meteorological Service of the Dominion of Canada*, 1888.—*Toronto General Meteorological Register*, 1889.

TRIESTE, OBSERVATORIO MARITTIMO.—*Rapporto Annuale*, 1887.

TUCUMAN, OFICINA QUIMICA.—*Boletín*, Tome II. Ent. 3.

TURIN, SOCIETÀ METEOROLOGICA ITALIANA.—*Annuario Meteorologico Italiano*, Anno VI. 1891.—*Bollettino Mensuale pubblicato per cura dell'Osservatorio Centrale di Real Collegio Carlo Alberto in Moncalieri*, Vol. IX. No. 12, to Vol. X. No. 11.

UPSALA, OBSERVATOIRE MÉTÉOROLOGIQUE DE L'UNIVERSITÉ.—*Bulletin Mensuel*, Vol. XXI. 1889.

UTRECHT, K. NEDERLANDSCH METEOROLOGISCH INSTITUUT.—*An attempt to compare the instruments for absolute magnetic measurements at different observatories*. By Dr. van Rijkevorsel.—*Nederlandsch Meteorologisch Jaarboek*, 1889.—*Onweders in Nederland*.

VIENNA, K. K. ACKERBAU-MINISTERIUM.—*Resultate forstlich-meteorologischer Beobachtungen*, 1885-7. Von Dr. J. R. von Lorenz-Liburnau.

VIENNA, K. K. CENTRAL-ANSTALT FÜR METEOROLOGIE UND ERDMAGNETISMUS.—*Beobachtungen*, Oct. and Nov. 1889, and Jan. to June 1890.—*Jahrbuch*, 1888.

VIENNA, OESTERREICHISCHE GESELLSCHAFT FÜR METEOROLOGIE.—*Meteorologische Zeitschrift*, 1890.

WASHINGTON, GEOLOGICAL SURVEY.—*Annual Report*, 1886-7.

WASHINGTON, HYDROGRAPHIC OFFICE.—*Pilot Charts of the North Atlantic Ocean*, 1890.—*Report of ice and ice movements in Bering Sea and the Arctic Basin*. By E. Simpson.

WASHINGTON, SIGNAL OFFICE.—*Bibliography of Meteorology*, Pt. 2, Moisture.—*Charts showing the normal monthly rainfall in the United States*. By H. H. C. Dunwoody.—*Cold waves and their progress. A preliminary study*. By Lieut. T. M. Woodruff.—*Corrections of thermometers*. By T. Russell.—*Danger lines and river floods of 1882*. By H. A. Hazen.—*Effect of wind-currents on rainfall*. By G. E. Curtis.—*First Report upon observations of atmospheric electricity at Baltimore, Maryland*. By P. Morrill.—*Monthly Weather Review*, Dec. 1889 to Sept. 1890.—*Popular essays on the movements of the atmosphere*. By Prof. W. Ferrel.—*Report on Lady Franklin Bay Expedition of 1883*. By Lieut. E. A. Garlington.—*Reports of the Chief Signal Officer, U.S. Army*, 1875, 1891-4, and 1896-8.—*The Aurora in its relation to Meteorology*. By A. McAdie.—*Thunderstorms of May 1884*. By H. A. Hazen.—*Tornadoes of May 29 and 30, 1879, in Kansas, Nebraska, Missouri, and Iowa*. By Sergt. J. P. Finley.—*Tornado of Aug. 28, 1884, near Huron, Dakota*. By Sergt. S. W. Glenn.—*Tri-daily Meteorological Record*, July-Dec. 1878.

WASHINGTON, SMITHSONIAN INSTITUTION.—*Report 1887*. Pt. 1.—*Reports of Prof. Joseph Henry, Secretary, for the years 1867-70, and 1874-6*.

WATFORD, HERTFORDSHIRE NATURAL HISTORY SOCIETY.—*Transactions*, Vol. V. Pts. 6 to 8.

WELLINGTON COLLEGE, NATURAL SCIENCE SOCIETY.—*Annual Report*, 1889.

ZI-KI-WHI, OBSERVATOIRE MAGNÉTIQUE ET MÉTÉOROLOGIQUE.—Bulletin Mensuel. Tome XV. 1889.

ZURICH, SCHWEIZERISCHE METEOROLOGISCHE CENTRAL-ANSTALT.—Annalen, 1888.

Presented by Individuals.

ÅNGSTRÖM, R.—Beobachtung über die Strahlung der Sonne.—Étude des spectres infra-rouges de l'acide carbonique et de l'oxyde de carbone.—Études de la distribution spectrale de l'absorption dans la spectre infra-rouge.

ATKINSON, E.—The Cotton Manufacture of the United States.

AUGUSTIN, DR. F.—Untersuchungen über die Temperatur von Prag.

BAKER, DR. H. B.—Malaria and the causation of Intermittent Fever.

BAYARD, F. C.—Abstract of Meteorological Observations taken at Wallington, 1889.

BERTOLANO, C. E. DR.—Observatorio Meteorológico de Manila. Observaciones Magnéticas, 1888.

BINYON, J. B.—Rainfall at Blackrock, near Cork, 1865-1889, and Dec. 1889 to Nov. 1890. (MS.)

BLACK, DR. W. G.—Sanitary State of Hong Kong in 1865.

BROWN, A., AND BOOBYER, P.—The Meteorology of Nottingham for the year 1889.

BROWN, S.—Report of the Great Storm at Hong Kong on May 29 and 30, 1889.

BRUMHAM, THE MISSES.—A chronological history of the weather and seasons and of the prevailing diseases in Dublin during forty years. By Dr. J. Rutty.—MS. Meteorological Notes, &c., compiled by the late Mr. G. D. Brumham.

BUCHAN, DR. A.—The Physics and Chemistry of the Voyage of H.M.S. *Challenger*, Part V. Report on Atmospheric Circulation.

CAMARA, A. A.—Analyse dos Instrumentos de Sondar e Perscrutar ossegredos da Natureza Submarinha.—Ensaio sobre as Construções Navaes Indigenas do Brasil.—Impressões de Uma Viagem do Pará ao Recife, passando por S. Miguel e Tenerife a bordo da Corveta *Trajano*.—Relatorio dos estudos feitos no interior do porto da Bahia.

CLARK, J. E.—The Natural History Journal and School Reporter, Nos. 118 to 126.

CLEMENTS, H.—The late great gale (Jan. 1890). (MS.)—The prediction of storms and the late great gale. (Nov. 1890.)

COOKE, R.—Meteorological Observations made at Detling, Dec. 1889 to Nov. 1890. (MS.)

COXEN, MRS.—Meteorological Observations made at Bullimba, Queensland, July 1889 to June 1890. (MS.)

CROWFOOT, MISS M.—Meteorological Registers kept at Kessingland, near Lowestoft, 1855-63, by Mr. E. Crowfoot. (MS.)

DANKELMANN, DR. VON.—Beiträge zur Kenntnis des Klimas des deutschen Togolandes und seiner Nachbargebiete an der Gold- und Sklavenküste.

DAVIS, W. M.—Ferrel's convectional theory of Tornadoes. By W. M. Davis and C. E. Curry.

DENZA, PADRE F.—La inclinazione magnetica a Roma.—L' Anticiclone del Novembre, 1889.—Le alte pressioni del Dicembre 1889 e Gennaio, 1890.

DINES, W. H.—On wind pressure upon an inclined surface.

DIXON, H. P.—Wiltshire Rainfall, Nov. 1889 to Oct. 1890.

DOYLE, P.—Indian Engineering, Vol. VIII., Nos. 4 to 23.

DUNCAN, J. W.—Meteorological Observations at Summerlands, Yeovil, Dec. 1889 to Feb. 1890. (MS.)

EDITOR.—American Meteorological Journal, 1890.

EDITOR.—Boletim meteorológico periódico quincenal. Dirigido por Noherlesoom, Nos. 5 to 12.

EDITOR.—Ciel et Terre, Deuxième Série, 5e Année, No. 21 to 6e Année, No. 20.

EDITOR.—Nature, 1890.

EDITOR.—Telegraphic Journal and Electrical Review, 1890.

EDITORS.—The Observatory, 1890.

EGAR, S.—Meteorological Observations made at Wryde, Dec. 1889 to Nov. 1890. (MS.)

EGGESON, C.—The daily area of rainfall in New South Wales, Nov. 1889 to May 1890.

EKHOLM, N.—Ueber die Einwirkung der ablenkenden Kraft der Erdrotation auf die Luftbewegung.

ELIOT, J.—On the occasional inversion of the temperature relations between the Hills and Plains of Northern India.

ELLIOTT, DR. G. S.—Meteorological Observations made at Caterham, Dec. 1889 to Nov. 1890. (MS.)

ELLIS, W.—Map of England and Wales, showing lines of equal magnetic declination for the year 1890.

- FINEMAN, C. G.—Néphoscope Marin.
- FINES, DR.—Revue Climatologique Météorologique Agricole et Sanitaire de l'année 1889 à Perpignan.
- FOX, W. L.—Meteorological Tables for Falmouth and the Scilly Islands, 1889.
- FRANCHI, S.—Anomalia della declinazione magnetica in rapporto con grandi masse serpentinosi.
- GLEDHILL, G. W.—Meteorological Observations made at Harrogate, Dec. 1889 to Nov. 1890. (MS.)
- GLYDE, E. E.—Abstract of meteorological observations made at Babbacombe, Torquay, 1889.—Eighth Report of the Committee on the Climate of Devon, 1889.—Meteorological Summaries, Jan. to Oct. 1890, made at Babbacombe, Torquay.—Notes on the Climate of the Watering Places of England in 1888, compared with London.
- GONZÁLEZ, B. C.—Ensayo de meteorognosia de la ciudad de Puebla.
- GREENWOOD, W. N.—Discussion of tidal observations at 18 stations on the West Coast of England and Scotland to determine the effect of Atmospheric Pressure on the Wave during November 1888.
- HALL, M.—Jamaica meteorological results, 1880 to 1890.—Jamaica rainfall, 1887-9.—Jamaica Weather Report, Nov. 1889 to Sept. 1890.
- HALLAM, T.—Meteorological Report, Albert Park, Middlesborough, Dec. 1889 to Nov. 1890. (MS.)
- HAMLIN, G.—Meteorological Observations made at Buckfastleigh, Dec. 1889 to June 1890. (MS.)
- HANDS, A. J.—Illustrated Catalogue of Lightning Conductors, Vanes, Finials, &c.
- HANN, DR. J.—Beiträge zur arktischen Meteorologie.—Bemerkungen über die Temperatur in den Cyklonen und Anticyklonen.—Das Luftdruckmaximum vom Nov. 1889 in Mittel-Europa, nebst Bemerkungen über die Barometer-maxima im Allgemeinen.—Die meteorologischen Ergebnisse der Lady Franklin Bay Expedition, 1881-3.—Tägliche Periode des Regenfalles in Wien.—Tägliche Periode des Regenfalles von Calcutta und Simla.
- HARRINGTON, G. F.—The chemistry of nature.—The sun not the source of heat and light to the solar system.
- HELLMANN, DR. G.—Die Anfänge der meteorologischen Beobachtungen und Instrumente.
- HINRICHES, DR. G.—Report of the Iowa Weather Service, 1878, Pt. 4; 1879, Pt. 4; 1880; 1882, Pt. 4; 1883, Pt. 4; and 1884.
- HJELTSTRÖM, S. A.—Sur la conductibilité de la neige.
- HOPKINSON, J.—Climatological Observations taken in Hertfordshire, 1887-8.—Fog Bows at Odsey. By H. G. Fordham.—Meteorological Observations at St. Albans, 1889.—Meteorological Observations at St. Albans, Dec. 1889 to Nov. 1890 (MS.).—On local scientific investigation in connection with Committees of the British Association.—Rainfall and water supply.—The Climate of Scarborough.—The Great Essex Earthquake of the 22nd April, 1884. By Prof. R. Meldola.—The rainfall of 17th and 18th July, 1890.
- HOWLETT, REV. J. A.—Meteorological Observations made at Hereford, Dec. 1889 to March 1890. (MS.)
- HUNTER, J.—Meteorological Observations at Belper, 1890.
- HUTCHINS, D. E.—Cycles of Drought and Good Seasons in South Africa.
- JACKSON, W. E.—Meteorological Observations made at Erenkouy, Constantinople, Sept. 1889 to Jan. 1890. (MS.)
- JUHLIN, J.—Sur la température nocturne de l'air à différentes hauteurs.
- KAMMERMANN, A.—Résumé Météorologique de l'année 1889 pour Genève et le Grand Saint-Bernard.
- KLOSSOVSKY, PROF. A.—Différentes formes des grêlons observés au sud-ouest de la Russie.
- LANCASTER, A.—Le Climat de la Belgique en 1889.
- LATHAM, B.—Report on the Sanitation of Bombay.
- LECKY, R. J.—Map showing for the Westminster Clock Bell the allowance of time to be made on account of the velocity of sound.
- LEE, G. J.—Meteorological Observations made at Kimberley, South Africa, Dec. 1889. (MS.)
- LLOYD, DR. H. J.—Meteorological Observations made at Barmouth, Dec. 1889 to Nov. 1890. (MS.)
- MACKERETH, REV. T.—Meteorological Observations made at Windermere, Jan. to Nov. (MS.)
- MARCEY, DR. W., F.R.S.—A chemical inquiry into the phenomena of human respiration.
- MARKHAM, C. A.—Meteorological Report for Northamptonshire, 1889, and Jan. to Sept. 1890.
- MARSTON, C. F.—Meteorological Observations made at Sutton Coldfield, Dec. 1889 to Nov. 1890. (MS.)

- MAWLEY, E.—Meteorological Observations taken at Berkhamsted, Dec. 26, 1889, to Dec. 18, 1890.—The Rosarian's Year Book, 1890.
- McLANDSBOROUGH, J., and PRESTON, A. E.—The Meteorology of Bradford, 1889.
- MERRIFIELD, DR. J.—Meteorological Summary for Plymouth, 1889.
- MOORE, DR. J. W.—Abstract of Meteorological Observations taken at Dublin, 1889.
- ORMEROD, G. W. (THE LATE).—Rainfall at Teignmouth, 1889.
- PEARSON, C. N.—Meteorological Observations made at Reading, Dec. 1889 to Nov. 1890. (MS.)
- PEEK, C. E.—Meteorological Journal kept at Exeter, 1755-1775. By Samuel Milford. (MS.)
- PENCK, PROF. A.—Klima-Schwankungen seit 1700 nebst Bemerkungen über die Klimaschwankungen der Diluvialzeit. Von Dr. E. Brückner.
- PHILLIPS, F. H.—Meteorological Observations made at Brighton, June to Nov. 1890. (MS.)
- PRINCE, C. L.—Nature's Secrets. By T. Willsford (1658).—Summary of a meteorological journal kept at Crowborough, Sussex, 1889.
- RAGONA, D.—Influenza delle condizioni atmosferiche sull' influenza.
- RICHARD FRÈRES, MM.—Notice sur les instruments enregistreurs construits par Richard Frères. 3rd edition.
- RIGGENBACH, DR. A.—Die unperiodischen Witterungserscheinungen auf Grund 111 jähriger Aufzeichnungen der Niederschlagstage.—Witterungs-Uebersicht der Jahre 1888 und 1889 sowie neue Normal-Mittel für Niederschlag und Temperatur.
- ROBINSON, W.—Report on the sanitary condition of Scarborough, 1889. By Dr. J. W. Taylor.
- ROUCH, A. L.—Observations made at the Blue Hill Meteorological Observatory, Mass., U.S.A., 1888.—Report of the New England Meteorological Society's Eighteenth Regular Meeting held at Providence, R. I., April 15th, 1890.
- RYLANDS, T. G.—Transactions of the Historic Society of Lancashire and Cheshire, Vol. VII. 1854-5.
- SALLE, OTTO.—Das Wetter, 1890.
- SANER, J. A.—Meteorological Observations made at Northwich, Dec. 1889 to Nov. 1890. (MS.)
- SANTILLÁN, R. A.—Apuntes relativos á algunos Observatorios é Institutos Meteorológicos de Europa.—Bibliografía Meteorológica Mexicana.
- SCOTT, R. H.—The variability of the temperature of the British Isles, 1869-83, inclusive.
- SHAW, REV. G. A.—Meteorological Observations made at Farafangana, S.E. Madagascar, April to Dec. 1889, and April to July, 1890. (MS.)
- SIMENS, W. von.—On the general system of winds on the earth.
- SINCLAIR, DR. A. W.—Meteorological Observations taken at Kwa Lumpur, Selangor, Malay Peninsula, May and June, and Aug. to Dec. 1888. (MS.)
- SINGER, DR. K.—Die Bodentemperaturen an der k. Sternwarte bei München und der Zusammenhang ihrer Schwankungen mit den Witterungsverhältnissen.
- SLADE, F.—Meteorological Observations made at Beckford, Tewkesbury, 1889.
- SOUTHALL, H.—The Recent Drought. (1889-90.)
- SPARKS, F. J.—Meteorological Observations made at Crewkerne, Dec. 1889 to Nov. 1890.—Rainfall at Crewkerne, 1889. (MS.)
- STELLING, E.—Bemerkungen zu den meteorologischen Beobachtungen des Observatoriums in Irkutsk für das Jahr, 1888.—Magnetische Beobachtungen im Lenagebiet im Sommer 1888 und Bemerkungen über die säculare Aenderung der erdmagnetischen Elemente daselbst.
- STOKES, J.—Annual Report on the health of Margate for 1890. By Dr. A. W. Scatlift.
- STUART, M. G.—Reports on the returns of rainfall and observations on the flowering of plants and appearances of Birds and Insects in Dorset during 1888.
- STURGE, R. F.—Thirty Years Weather at Bristol.
- SYMONS, G. J.—Annuaire Météorologique pour l'an XIV. de l'ère de la République Française. Par J. B. Lamarek.—Coefficienti per la temperatura e per la pressione atmosferica nel barometro registratore Richard. Di Prof. D. Ragona.—Colpo d'occhio su' grandi fenomeni atmosferici notati alla privata stazione meteorologica in Roma negli anni 1865-7 in relazioni alle burrasche. Da C. Scarpellini.—De l'accord entre les indications des couleurs dans la scintillation des étoiles et les variations atmosphériques. Par Ch. Montigny.—Die Temperatur-Verhältnisse der Jahre 1848-63, an den Stationen des österreichischen Beobachtungs-netzes. Von Dr. C. Jelinek.—Die Witterungsverhältnisse von Berlin. Von H. W. Dove.—Essai sur l'Electricité atmosphérique. Par M. L'Abbé Hervieu.—Études climatologiques sur le département de la Haute Savoie. Par P. M. Vaullet.—Étude sur les phénomènes, l'aménagement et la législation des eaux au point de vue des inondations. Par A. Monestier-Savignat.—Géographie Physique de la Mer Noire de l'intérieur de l'Afrique et de la Méditerranée. Par A. Dureau-de-Lamalle.—Histoire de l'eau. Par E. Bonant.—Il Congresso Internazionale

dei Meteorologisti riunito a Vienna dal 2 al 16 Settembre 1873. Relazione del P. F. Denza.—Instructions météorologiques et tables usuelles. Par M. E. Renou.—Le baromètre appliqué à la prévision du temps en France. Par J. B. Plumadon.—Leçons de Cosmologie adressées à Monsieur le Verrier.—Les Inondations. Par A. Landrin.—Les phénomènes de l'atmosphère. Par F. Zurcher.—Lithologie atmosphérique. Par J. Izarn.—Mémoire sur les anémomètres à indications continues établis près Cherbourg.—Note sur un anémomètre totalisateur à compteur électrique. Par M. Le Général Morin.—Nouveau baromètre enregistreur à mercure. Par A. Redier.—On barometric oscillations during thunderstorms, and on the brontometer.—Premières Notions de Météorologie et de Physique du Globe. Par M. F. Hément.—Pressione atmosferica ridotta al medio livello del mare in Modena. Di Prof. D. Ragona.—Report on the Meteorology of Toronto. By Lieut. Col. E. Sabine, F.R.S.—Results of the monthly observations of Magnetic Dip, Horizontal Force, and Declination, made at the Kew Observatory, April 1869 to March 1875.—Résumé Météorologique de l'année 1866 pour Genève et le Grand St. Bernard. Par E. Plantamour.—Riassunto dell' osservazioni meteoriche eseguite nelle Stazioni presso alle Alpi Italiane nell' anno 1872-73. Del P. F. Denza.—Sur la distribution de la nébulosité moyenne à la surface du globe. Par M. L. Teisserenc de Bort.—Symons's British Rainfall, 1889.—Symons's Monthly Meteorological Magazine, 1890.—Table of the corrections for reducing observations of the barometer to 32° Fahrenheit. By J. Glaisher, F.R.S.—Tafeln zur Reduction der in Millimetern abgelesenen Barometerstände auf die Normal-Temperatur von 0° Celsius. Von J. J. Pohl und J. Schabus.—The Physical System of the Universe. By S. B. J. Skeretchly.—Torrents, fleuves, et canaux de la France. Par H. Blerzy.—Traitez des baromètres, thermomètres, et notiomètres ou hygromètres. Par M. Dxxx.

TAYLOR AND FRANCIS, MESSRS.—Taylor's Calendar of the Meetings of the Scientific Bodies of London, for 1890-91.

TAYLOR, DR. J. C.—Meteorological Observations at Las Palmas, Grand Canary, Oct. to Dec. 1888; Jan. 1889 to June, Sept. and Oct. 1890.

TENISON, E. H. R.—Meteorological Observations made at Bexhill-on-Sea, Dec. 1888 to Nov. 1890. (MS.)

TOMLINSON, S.—Bombay Waterworks. Report on Pawai project.

TRIPLE, DR. J. W.—Winds, with some remarks on their sanitary effects.

TYRER, R.—Rainfall in the County of Gloucester, Jan. to Nov.—The Meteorology of Cheltenham, 1889.

VEEVERS, R.—A Cruise in the Mediterranean.

VELSCHOW, F. A.—On the Cause of Trade Winds.

VENTOSA, V.—Método para determinar la dirección del viento por las ondulaciones del borde de los astros.

WALKER, T.—Meteorological Observations made at Addington Hills, Dec. 1889, Feb. and Apr. to Nov. 1890.

WATSON, REV. J.—Meteorological Observations made at Nuneaton, July 1890.

WILD, H.—Neuer Anemograph und Anemoscop.—Ombrograph und Atmograph.

WILLIAMS, DR. C. T.—Photograph of the Tower of Winds, Athens.

WORIKOF, DR. A.—Voyage aux salines d'Iletz et au pays voisin.

WOOD, B. T.—Traces from Richard Barograph at Conyngnam Hall, Knaresborough, Yorks, 1879.

APPENDIX VII.

REPORTS OF OBSERVATORIES, &c.

THE METEOROLOGICAL OFFICE.—Lieut.-Gen. R. Strachey, R.E., C.S.I., F.R.S., Chairman of Council; Robert H. Scott, M.A., F.R.S., Secretary; Nav.-Lieut. C. W. Baillie, F.R.A.S., Marine Superintendent.

MARINE METEOROLOGY.—*Current Charts for all Oceans*.—The extraction of data for this work has been continued. The number of Remark Books which have been consulted during the year 1890 has been 5,600, covering the interval from 1862-1885.

The Meteorology of the Red Sea, and also of Cape Guardafui.—The charts for Cape Guardafui are complete. The work is in the hands of the printer and will appear shortly. The Red Sea charts are still under treatment, but it is expected that they will ere long be passed on to the engraver.

The Aden Cyclone Charts.—These have now been engraved. The only supplemental matters now required in addition, are the remarks to accompany the charts.

The Cyclone Tracks of the South Indian Ocean.—This work is now issued.

The Meteorology of the South Sea.—This has made rapid progress during the year. The whole of the material contained in the office logs has already been dealt with, and a commencement is being made with the logs of H.M. Ships obtained from the Record office. The region under discussion is the track from the Cape of Good Hope to New Zealand.

WEATHER TELEGRAPHY.—This department of the office shows no change. The *Weekly Weather Report*, with its monthly supplements, has been brought up to date, and the inspection of the Fishery barometers was completed in the course of last summer.

LAND METEOROLOGY OF THE BRITISH ISLES.—Parts II. and III. of the *Quarterly Weather Report* for 1880 have appeared, and Part IV. will shortly come out. With the issue of this part the series of *Quarterly Weather Reports*, accompanied by copper-plate reproductions of the various continuous curves furnished by the seven self-recording observatories, comes to an end.

The further issue of *Hourly Readings* has been discontinued, and in its stead it is intended to publish in future hourly means of the different elements for five-day periods, and also for each month, and for the year. The volume for 1887, which will commence the series, is in the press and will shortly be published. A discussion of the mean results obtained from the Harmonic analysis of the pressure and temperature observations made at Greenwich for 20 years, and at the observatories of the Meteorological Council for 12 years, is also passing through the press and is nearly ready for issue.

The volume of *Observations from Stations of the Second Order* for 1886 has appeared, and that for 1887 is more than half printed.

The observations made at Sanchez, Samaná Bay, St. Domingo, by the late Dr. W. Reid, have now been published.

In addition, the Registrar General for Ireland has been supplied with returns from 11 stations for his *Quarterly Reports*.—*February 1891.*

ROYAL OBSERVATORY, GREENWICH.—W. H. M. Christie, M.A., F.R.S., Astronomer Royal; Departmental Superintendent, William Ellis, F.R.A.S.; Assistant, William C. Nash. No change calling for any special remark has been made in the routine of observations or reductions during the year 1890.

The meteorological photographic records are maintained as in former years: these include records of the barometer, of the dry and wet bulb thermometers, and of Thomson's electrometer. The Osler anemometer, giving continuous record of the direction and pressure of the wind and of the amount of rainfall, and the Robinson anemometer giving record of velocity, are also in good order. Since the summer of the year 1889, the old Robinson anemometer by Negretti and Zambra has been mounted by the side of the larger instrument by Browning, which has been in use since the year 1866, and corresponding readings of the two instruments have been taken daily for the purpose of comparison of their records.

The observations of the temperature of the air by thermometers placed in a Stevenson screen are still maintained, as well as observations of thermometers placed on the roof of the Magnet House 20 feet above the ground.

The volume for the year 1888 has been recently published, and the printing of that for 1889 is nearly completed.

The collection and reduction on one system of the results of the magnetic photographs from 1865 to 1882 in a manner corresponding to that adopted in 1888 and following years, has made considerable progress. When completed, it is proposed to undertake the preparation of a more complete system of meteorological averages than at present exists, the material that has accumulated since the establishment of the Magnetical and Meteorological Observatory in the year 1841 being used to give daily means of various meteorological elements on an average of 50 years' observations.—*February 2nd, 1891.*

ROYAL OBSERVATORY, EDINBURGH.—Ralph Copeland, Ph.D., F.R.A.S., Astronomer Royal for Scotland.

The meteorological work at the Edinburgh Royal Observatory during the past year has consisted of the reduction of the observations taken at 55 stations of

the Scottish Meteorological Society, and the preparation of weather returns for the Registrar General for Scotland. These comprise a monthly summary for eight of the chief towns in the country, and a quarterly summary for the whole of the stations. Daily readings are taken at the observatory at 1 p.m., and the earth thermometers are noted with extreme care every Monday at noon. At the close of the year a new rain gauge was started 12 inches above the ground-level at the request of Mr. Symons. The rain caught by it promises to differ materially from the record given by the old gauge on the roof, which is higher by 28 feet.—*February 9th, 1891.*

THE KEW OBSERVATORY OF THE ROYAL SOCIETY, RICHMOND, SURREY.—G. M. Whipple, B.Sc., F.R.A.S., Superintendent.

The several self-recording instruments for the continuous registration respectively of atmospheric pressure, temperature, and humidity, wind (direction and velocity), bright sunshine, and rain have been maintained in regular operation throughout the year.

The standard eye observations for the control of the automatic records have been duly registered, together with the daily observations in connection with the U.S. Signal Service synchronous system.

The tabulations of the meteorological traces have been regularly made, and these, as well as copies of the eye observations, with notes of weather, cloud, and sunshine, have been transmitted to the Meteorological Office.

Tables of the monthly values of the rainfall and temperature have been regularly sent to the Meteorological Sub-Committee of the Croydon Microscopical and Natural History Club for publication in their *Proceedings*. Detailed information of all thunderstorms observed in the neighbourhood during the year has been forwarded to the Royal Meteorological Society soon after their occurrence.

The electrograph has been in constant action throughout the year, and comparisons with the portable electrometer have been made from time to time.

The supply of the chart exhibiting copies of the daily traces of the self-recording meteorological instruments at the Observatory ceased by instructions from the *Times* office on March last, after continuous publication for 14 years.

The fog gauge set up on the north side of the Observatory in 1884 has been recently dismantled, as it was not found possible to measure the intensity of this phenomenon by its means.

At the request of the Meteorological Council, the barograph and thermograph which have been stored at the Observatory since their return from the Armagh Observatory in 1886, have been thoroughly re-fitted, and, after a short experimental trial at the Observatory, re-packed and forwarded to the new Observatory at Fort William for use at the low-level station worked in conjunction with the Observatory erected on the summit of Ben Nevis. In June last, on receipt of information from Mr. Omond, the superintendent of the Ben Nevis Observatory, that the new building was ready for the reception of the instruments, Mr. T. W. Baker proceeded to Fort William and set them up and put them in proper adjustment. Having done this, and instructed Mr. Omond in their manipulation and the attendant photographic operations, he returned to Kew, leaving the establishment in good working order in July. Owing to difficulties attendant on the regular supply of gas, it was found advisable to adapt the burners for the consumption of mineral oil, on the pattern of those employed at the Observatory at Valencia Island, Ireland, for the last 22 years, with great success.

During the past summer 225 series of observations of the sun's actinic power have been made with Violle's actinometer, described in the last Annual Report, upon the plan arranged by General Strachey and Mr. Blanford.

The electrical anemograph, after working on the staging erected on the roof, 14 feet to the north of the Beckley instrument, and recording by means of a battery composed of eighteen Fuller's cells, was dismantled on July 22, and packed for storage. During the period it was at work, the traces were forwarded weekly to the Meteorological Office.

At the request of the Meteorological Office, various specimens of lubricating oils have been applied to the gearing of the anemograph with the view of determining the best for use under the varying conditions to which it is exposed.

At the suggestion of General Strachey, Chairman of the Meteorological Council, a new departure has been made in the photography of clouds during the

past year, with the view of simplifying the operations of determining the height and velocity of their movement. Both cameras have been rigidly fixed on their stands, with the axes of their lenses pointed directly to the zenith, and photographs are now taken simultaneously of the area of the sky surrounding the zenith within a circle of a radius of about 15° . A frame has been constructed in which these photographs are superposed one on the other, so that the two pictures shall appear to coincide, and a simple measurement of the distance between the images of the zenith points, which are marked by intersecting lines, gives a means of readily determining the height of the cloud above the surface of the ground. A second measurement made in like manner of the displacement of the zeniths in a second pair of photographs taken after a given interval of time serves to show the rate of travel of the cloud and the direction in which it is moving at the instant of observation. Twenty groups of clouds, giving heights extending from $1\frac{1}{2}$ miles to 8 miles, and rates of motion from 5 miles to 64 miles per hour, have been photographed and measured in this manner during the past summer. A light framework, 12 feet in height, has been constructed, which is occasionally erected above each of the cameras in order to verify the position of their zenith points and the orientation of the cross lines on the photographic plates.

The Committee having considered the desirability of possessing some thermometers which had been accurately compared with the hydrogen thermometer of the Conservatoire des Poids et Mesures, at Paris, instructed Mr. Whipple to convey to the director of that office the set of three closely graduated mercurial thermometers, whose errors were investigated in 1879, by Professors T. E. Thorpe and Rücker (see *British Association Report*, 1881, p. 540), and also an alcohol thermometer graduated at Kew for the special purpose of the comparison, its scale extending from -100° to $+90^\circ$ Fahr. The examination of these thermometers has now been completed, and M. Benoit has sent his report upon them to Kew Observatory.

In addition to the usual instruments submitted for verification, the Committee have been called upon for special examination and reports upon the following articles: the Admiralty, for a Gun Director Telescope, and new pattern Officer's Telescope; the War Office for a barometer supplied to the Netley Hospital; and the makers for a new Watkin's Clinometer, and Watkin's Aneroid with open scales: as well as various instruments for the Anglo-German Boundary Commission on the Gold Coast.

The Chairman of the Committee, with a view of making the public more conversant with the systems of verification and rating in use at the Observatory, prepared in the early part of the year a pamphlet entitled "Tests and Certificates of the Kew Observatory." Of these 1,000 copies were printed, of which 200 have been distributed to the principal opticians and instrument makers.

The necessary apparatus to enable the examination of photographic lenses for cameras to be prosecuted at the Observatory, with the view of granting certificates to the owners or purchasers of such articles, has been prepared, and it is in contemplation to adopt two such schemes of examination of lenses, one, a comparatively rough or cursory trial which will enable a person to form a general idea of the capabilities of a lens, whilst the more lengthy and careful trial, for which a higher fee will be charged, will give full particulars as to the various qualities an acquaintance with which is necessary to possess a full knowledge of the instrument. Captain Abney and other gentlemen have rendered the Committee much assistance in the practical arrangement of the details of this lens testing.—*January 20th*, 1891.

RADCLIFFE OBSERVATORY, OXFORD.—E. J. Stone, M.A., F.R.S., Radcliffe Observer.

The following is a report on the meteorological work of this Observatory for the year 1890:—

The eye-observations have been made on the plan stated in the report for 1889. But, with respect to the continuous registration of the meteorological instruments, it has been found much more convenient to adhere to the plan on which the meteorological reductions have been made in previous years; and, to begin and end the day at noon.

The self-registering instruments have worked satisfactorily throughout the year ; and the argentic gelatino-bromide paper, brought into use in February 1890, has given satisfaction.

Weather Reports have been sent, as in previous years, daily (by telegram) to the Meteorological Office ; bi-monthly to the United States Signal Office ; monthly to the Registrar-General and local newspapers ; and yearly to Symons' *British Rainfall* ; and to others by request.

The eye-observations are reduced to date. The *Meteorological Results* for 1886 have been printed, and were distributed last November. The *Results* for 1887 are under discussion.

Dr. Haldane and Mr. M. S. Pembrey have completed their experiments, at the Observatory, on the moisture in the air, and their results have been printed in the *Philosophical Magazine* for 1890, page 806.

The mean temperature of the air for last December was $28^{\circ}\cdot9$, or $10^{\circ}\cdot6$ below the average of the last 85 years' observations. The mean temperature for the day on December 22nd, was $10^{\circ}\cdot8$, being $28^{\circ}\cdot0$ below the average temperature for that day : the lowest reading for the past winter, $8^{\circ}\cdot0$, was also recorded on that day. The total rainfall for the year 1890 was only $18\cdot400$ ins., which is $7\cdot994$ ins. below the average of the last 89 years' observations, and smaller quantities have fallen only in the years 1854, 1864, and 1870 during this period. The total amount of bright sunshine for the year was 1,411 hours. Only 6 hours were recorded during December.—*February 19th, 1891.*

Note on a peculiar development of "Cirrus" Cloud observed in Southern Switzerland.

By ROBERT H. SCOTT, M.A., F.R.S.

[Received December 2nd, 1890. Read January 21st, 1891.]

On Friday, August 22nd, 1890, I was at San Carlo, in the Val Bavona, a tributary of the Val Maggia, in the Canton Ticino. San Carlo lies on the northern side of the Basodino, a well known peak in that district.

The weather had been exceedingly bright and warm for several days. At about 2 p.m. I noticed "cirrus" coming from the north-west, over the St. Gothard district, which lay nearly due north of my position. The cirrus appeared to rise from a distinct bank of stratified cloud of small extent, not dense enough even to deserve the name of "stratus." From this depended a decided tail, or funnel-shaped cloud. This precisely resembled the cloud funnels which accompany whirlwinds, or so-called tornadoes.

I at once remarked to my companion, "that means a break-up of our hot weather," and sure enough, on the 24th, two days later, a terrific thunderstorm burst over the district, and lasted in those valleys for about 24 hours. This electrical disturbance was accompanied by very serious hailstorms, which devastated the agricultural products, such as grapes and maize, in some parishes. At Bignasco, where I was staying, the fall on the 24th was 93mm (8·66 inches).

The succeeding week was very wet, the fall being such as to raise the level of the Lago Maggiore by about six feet. The wet weather terminated on the 31st, with another 24 hour thunderstorm, also accompanied by local tornadoes and hail. Hailstones were reported at Monte Generoso, of which six

weighed a kilogramme. At all events a hailstone weighing 5 oz. is a formidable missile. Enormous damage was done near Como.

The appearance of a possible whirlwind cloud, at the level of cirrus, followed by electrical manifestations of extraordinary violence and continuance, is my excuse for submitting this note to the Society.

I regret not having made a sketch, so as to record, however roughly, the phenomenon.

DISCUSSION.

Rev. W. CLEMENT LEY wrote:—"Was any spiral or whirling motion discernible in the funnel shaped cloud tail?"

"On the reply to this query a good deal depends, both of the value of the Note, and of that of my discussion following its lines.

"'Tails,' of what I have termed 'pseudo-cirrus pendulus' can often be seen (at the close of fine summer weather) depending from a patch of rather cumuli-form ice-cloud, perpendicular when the movements of the atmosphere in the neighbourhood of the cloud are uniform; inclined at various angles to the earth's surface whenever (as is most commonly the case) when the upper surface of the cloud is moving with a velocity or direction differing from that of the air below, where the tail of descending ice-crystals undergoes evaporation. Here spiral movements are not visible, and all questions relating to the cloud-form are very simple.

"If, on the other hand, spiral movements were observed at the cirrus altitude, this Note will ultimately involve an entirely novel departure in the dynamical theory of the movements of the atmosphere.

"'Funnel clouds' at the base of Cumulus and Cumulo-nimbus are very common indeed. To explain the formation of such clouds in the Cirrus region would be a new, and, I think, a most difficult task."

Dr. MARCET said that it was remarkable that a violent storm occurred in the Valley of Joux, near Neuchâtel in Switzerland, at about the same time as the storm described by Mr. Scott. This storm was very destructive, many houses and a large number of trees being blown down.

Mr. SYMONS said that the latter part of August 1890 was remarkable for the frequency and severity of the tornadoes or whirlwinds which prevailed. Among the most violent were the following:—

On the night of August 15th, a storm in the vicinity of Carcassonne, in the Department of Aude, in the South of France, in which the damage, chiefly by hail, was found to have exceeded 25,000,000 francs (one million sterling).

On the night of the 18th, two storms, in each of which great wreckage was produced by wind. The first was near Miremont in the Department of Dordogne in the south-west of France; and the other passed south-west of Paris, from Dreux in Eure et Loire, to near Mantes, in Seine et Oise. The ruins at Dreux (where the path of the whirlwind went right across the town) had been visited and photographed by M. Teisserenc de Bort and by Mr. Rotech.

On the night of the 19th a similar storm, with excessive wind and hail, visited St. Claude in the Jura, and crossed the frontier into the Canton Vaud, Switzerland, wrecking churches, houses, and vineyards.

On the 25th a destructive storm passed over Citta di Castello (Perugia), about 100 miles north of Rome, which overthrew four churches, did great damage to house roofs, and injured many persons. At Pistuno, in the same neighbourhood, a house fell and buried several persons, and the adjacent Commune of Citerna was devastated.

Mr. WHIPPLE said that he was much interested in this account of cirrus cloud formation, as he had been keeping a particular watch for the past year or so in order to secure good photographs of cirrus clouds. He called the attention of the Fellows to the desirability of carrying a small photographic camera, such as the "Kodak," with them when travelling, as they would then be prepared to take photographs of clouds or other objects possessing meteorological interest which they might happen to meet with. He had seen, a few hours previously, at the Royal Astronomical Society, an engraving of ball lightning observed in

the streets of Toulouse, and thought that an observer who might by chance obtain a photograph of this phenomenon would be indeed a most fortunate individual, and amply repaid for his trouble in carrying the apparatus.

Mr. BRUCE remarked that shortly after the occurrence of the storm described by Mr. Scott, he travelled by railway from Basle to Rheims, and along the whole French route he saw evidence of the violence of the storm.

Mr. SCOTT stated that as far as he was able to fix the level of the cloud he observed, it appeared to be at the level of cirrus. At all events, it must have been above 12,000 feet high, for it was clearly higher than the St. Gothard peaks, which reach about to the level of 10,000 feet. He begged to append a copy of a letter on the subject of his paper which he had received from Dr. HANN.

Extract from a letter from Dr. JULIUS HANN, dated Nov. 20, 1890, to Mr. Scott:—"Your cirrus observation is very interesting. I myself have never seen anything of the kind, or, at least, my attention has not been specially attracted by it. Possibly, at the time of your observation, there existed a sort of unstable equilibrium between the upper and lower strata of the atmosphere. I think that I have somewhere or other drawn attention to the circumstance that not very uncommonly on the south side of the Alps the lower warm strata on the lee side (*Wind Schütze*) of the Alps are covered at a great height by colder currents. It would take some time before the reaction between the two brings about a condition of more stable equilibrium. Your observation of a sort of funnel cloud (*Trombe*) appearing at the height of cirrus might easily fall in with this idea. The Alps would certainly, up to the level of 8,000 metres, delay the mixture of these currents, so that the upper currents must move at the level of 5,000 metres and upwards. Many phenomena at the commencement of thunderstorms on the Plain of Lombardy, especially as to their frequent accompaniment by hailstorms, might be easily explained on this idea.

"At all events, you should print your Note, if possible with a simple sketch, as it is new, and deserves to be generally known."

SOME REMARKS ON DEW.

Being Notes on Observations which were made to discover whether Dew is all deposited from the Air, or if some also comes from the Earth and Plants, and also what quantity is formed during the Year.

By COLONEL W. F. BADGLEY, F.R.Met.Soc.

[Received November 15th, 1890.—Read January 21st, 1891.]

I WAS first induced to make these inquiries by seeing that my camp boxes in India, after being on the ground at night, were wet underneath, and by noticing that the arrangement of the drops of dew on the edges and points of the leaves of corn and other plants was such as could not have been due to the deposit of dew from the air. I should have followed up my ideas much earlier but for the difficulty of deciding on a method of working them out. I had not seen Wells' book on *Dew*, and the only meteorological work I had read hardly mentioned dew at all. It was not till the beginning of 1888 that chance led me to begin observations. At that time I received a box with a thin zinc lining; I cut the zinc into plates, exposed them, and found that owing to their thinness and dullness through oxidation they condensed the dew perfectly, and that my chief difficulty was ended.

I made the first set of observations in India in 1888, while in camp on the Pulney Hill plateau, in latitude 8°30' N., and at heights varying from 7,500

to 4,500 feet above the sea. They were few, as the camp moved every day, and there were not many suitable places with short grass and free exposure to the sky to be found, and also because the wind, which was from the North-east and very dry, blew strongly for some time and dried up the dew as it was deposited. During the best weather this wind would often set in towards morning after a calm night, so I always covered the plates over at 4 p.m. and examined them at sunrise.

The second series of observations I made in 1889-90, at Kyrewood House, near Tenbury, in Worcestershire, at a height of about 400 feet above the sea, the locality being a tennis lawn between a garden and an orchard, with a pretty fair exposure to the sky and grass kept short by a machine.

I used two zinc plates about $8\frac{1}{2}$ inches in diameter and dull with oxidation. These I laid on the grass about sunset and took up about sunrise. One side of each plate I dried, and weighed the plate with the dew on the other side. The dew on the grass, which had been covered by one of the plates I took up with blotting paper, and added its weight to that of the dew on the underside of the plate. I made the measurement of the dew by weights representing drops, 800 of which were made to go to an ounce avoirdupois, as I found that 10,000 such drops would cover my plate (with an area of nearly 58 square inches) just 1 inch deep, and that therefore, in recording, all that would be needed to convert a drop into its depth in decimals of an inch, would be to apply a decimal point and three ciphers.

In the English experiments I exposed a third plate on a tripod at 5 feet from the ground. The quantities of dew on the two sides of this plate were usually equal or nearly so, but occasionally there was a decided difference, and more often when this happened the greater quantity was on the lower side of the plate. In the record sent to the Society¹ I have entered the half of the whole amount of the dew on both sides, except when it rained, when I give the quantity on the underside.

At the end of the twelve months' record I have added a table giving some experiments made to find what quantity of dew is exhaled by plants. There are not many of these, as I could make none when the leaves were wet in the evening with rain, and I rejected those made on nights when it rained, as some of the rain might have trickled into the tube. This article, in which the exhalation was collected, is a thin zinc bottle about 10 inches long by $8\frac{1}{4}$ in diameter at its widest part. I set it an inch or more above the ground, according to the plant examined; some of the leaves being inside, I closed the mouth with a crumpled leaf, and in the morning measured the area of the leaves and weighed the water in the bottle, and from these have calculated the depth of dew.

In the records of observations with zinc plates, column 1 gives the date of the day following the night of observation. Columns 2 and 3 give the quantities of dew collected on the upper and undersides of plates exposed on the grass. Rain or wet fog during the night is shown by a dark line in

¹ These observations are preserved in the office of the Society.—Ed.

column 2. Column 4 gives the dew collected on one side of a plate supported at 5 feet from the ground. Columns 5 and 6 give the minimum temperature for the night of observation and the maximum for the date. Column 7 gives the humidity of the evening before the night of observation. And the remaining columns give roughly the direction and force of the wind and the aspect of the sky.

A total of the dew collected on the plates exposed on the grass is given at the end of each month, and to this has been added what, by calculation, ought to have been found on the upper side of the plate on nights when it rained, and this increased total is taken as the dew for the month.

The following are the conclusions which I deduce from the observations, and my reasons for them :—

I. That the earth always exhales water vapour by night, and probably a greater quantity by day.

The record of observations shows that on many nights during the twelve months, a considerable quantity of water vapour rose from the earth and was condensed as dew on the under-surface of the plates laid on the grass. It is apparent, also, that the amount of dew condensed from this vapour depended on the favourableness of the weather. On nights with a clear sky and a gentle wind the quantity was always large, while the more unfavourable to radiation and the more windy the night, the less dew there was. Therefore, presumably, had there been no wind, and had the plates being cooled equally by radiation every night, the earth vapour would have been condensed equally on every night. Also, as Wells in his treatise on *Dew* has shown, that in favourable weather dew is formed all through the night, and as it appears from my observations that much of the dew comes from the water vapour given off by the earth, it follows that vapour issues from the ground continuously during the night. If it do so throughout the night, it may be concluded that it continues to do so during the day, and that the earth always exhales water vapour.

As to the second part of my theorem, that the earth exhales a greater quantity of water vapour by day than by night, I am undertaking some experiments to test the quantities, and intend to continue them for twelve months.

II. That the quantity of water vapour given off by the earth is always considerable, and that any variation in the quantity is mainly due (in England) to the season of the year.

I have taken the average quantity of dew collected on the underside of the grass plate on those nights in each month which were most favourable to radiation or were frosty, and dividing these by the number of hours during which the plates were exposed, I find that the quantities condensed, in decimals of an inch per hour, are as follows :—

November	...	·00048	March	...	...	·00048
December	...	·00048	April	...	...	·00050
January	...	·00087	May	...	...	·00055
February	...	·00084	June	...	...	·00072

July ...	...	·00061	September ...	·00058
August ...	...	·00061	October ...	·00049

That is to say, the exhalation in summer is twice as much as in winter. The mean of the above figures is ·000501, which is the average quantity of dew from the earth vapour in an hour at night, and if the earth gives off as much vapour during the day as during the night, then during the past twelve months the earth has exhaled vapour sufficient to produce more than a hundredth of an inch of water daily, or nearly $4\frac{1}{2}$ inches in the year, which is over a sixth of the rainfall in this county (Worcestershire); as the weather during this time has been more dull and cold and less rainy than usual, this amount of moisture exhaled is below the yearly average.

III. That the greater part of the dew comes from the earth vapour.

This is plain enough from an inspection of the record. During the twelve months 1·2040 inches of dew were collected on the underside of the grass plate, and ·8677 inches on one side of the plate raised 5 feet from the ground. That is, the dew from the earth vapour exceeded that from the air vapour in the proportion of more than 8 to 1.

On particular nights, when everything is favourable, the dew condensed from the air may exceed that from the earth vapour, and there are seven instances of this in the record in the months of September and October; but taking the year through, the quantity supplied by the earth is, as shown above, very much more than that from the air, and I am surprised that so acute an observer as Wells should have missed this. It was no doubt owing to his observing on fine nights only, for his cotton wool method was not suited to any other weather. It will be noticed that on the seven nights referred to, and as a general rule on every night on which dew was found on the raised plate, the quantity on this plate has exceeded that on the upper side of the grass plate, and that the wind was calm or very light. Also, that in most cases where dew was found on the upper side of the grass plate and none on the raised plate, there had been moderate or strong wind. The wind, in fact, moving more slowly along the ground than at 5 feet above it, was able to get at the raised plate more easily, and in the one case to dew it, and in the other case to dry it, more thoroughly than the plate on the grass.

I think it probable that on favourable nights the greater part of the vapour from the earth is condensed before it passes the surface of the grass, and that whatever dew is found on the upper surface of the grass plate on such nights is for the most part moisture brought by the air from a distance.

IV. That plants exhale water vapour, and do not exude moisture.

At the end of the record of observations with zinc plates I have given a table showing the results of some experiments made with a zinc bottle, in which I enclosed sprays of different plants on nights more or less favourable to radiation. In this table I have given, as in the previous ones, the aspect of the sky, but omitted wind, temperature and humidity, as not necessary to the inquiry.

The bottle was set in the evening, when the plants were dry, before dew began to form, and was supported horizontally, at whatever height was re-

cessary, with some of the plant experimented on inside. The mouth was closed lightly with a crumpled leaf and the results examined in the morning.

I found that some plants gave better results than others, notably oats, some plants of which had sprung up in the garden from seed brought with the manure, and which I had saved from the gardener's clutches. Grass disappointed me; but its situation in a meadow, where the bottle was somewhat sheltered by the surrounding grass, may have had to do with the small results.

I was quite satisfied that the water collected in the bottle came from the plant, but in case an objection might be made that it came from the air in the bottle and not from the plant, I tried the experiment, on a clear night, of setting out the empty bottle, closed as usual with crumpled leaves, and in the morning found no result that would affect my balance. The experiments recorded were rough, but they were on a sufficiently large scale to produce easily measurable results, and no trial was made when the plants were wet from previous rain, nor was a trial recorded if rain fell in the night for fear some drops might have trickled into the bottle. Mr. Aitken's observations, however, sufficiently prove that plants produce water in quantity.

On examining the bottle in the morning I found that moisture was collected on its inner surface—sometimes as much as a teaspoon full—and that the plant was itself nearly dry. No other explanation of these circumstances occurs to me except that the moisture found in the bottle was given off as vapour by the plant, and was condensed from the air, with which it then mixed, by the cold sides of the bottle.

I believe that plants give off aqueous vapour in the same way that they give off carbonic acid and other gases, and that the drops seen on the edges of leaves on fine nights are so formed because of the immediate condensation of the vapour on its issue from the pores of the plant, and if examined would be found to be pure water—dew in fact—and in no manner mixed with the juices of the plant, which would certainly be the case were it an exuded fluid.

I may remark that where I have mentioned the earth and the vapour from it in the above notes, I have included the grass covering and the vapour from this grass. It would have been uselessly confusing to have made a distinction between the soil and its covering before this, but I will now detail an experiment made to try to find what part of the dew on the underside of the plate on the grass might be supposed to come from the earth vapour and what part from the plant vapour. I cut the grass and weeds from a measured piece of the lawn, and took the area of all the green leaves. I found that the 58 square inches of soil covered by my grass plate bore upon it 142 square inches of leaf, taking both sides of the leaf into account. The average depth of dew from the vapour of plants in all my experiments is $\cdot 000465$ of an inch, which, multiplied by 142, the area of the grass, and divided by 58, the area of the plate, gives $\cdot 001121$ inch as the average quantity the plate would have condensed from a mixture of these plants. The average quantity of dew condensed on the underside of the grass plate on the same nights is $\cdot 004057$ inch, of which, therefore, about three parts

came from the soil, and one part from the grass on it, if the grass be allowed to represent the mixed plants. So much, however, cannot be said to hold good for the whole year. These experiments were made from April to September. Probably in winter plants—even those that are evergreen—give off little water vapour, while the soil, retaining its heat unchanged at a short distance below the surface, continues its exhalation of vapour with much less change.

The total quantity of dew collected on the grass plates in the year was 1·6147 inches.

I will end my notes with a few remarks about some peculiarities that may be noticed in the daily record.

The case of November 26th and 28th is peculiar. On the first date there were 89 drops on the upper side of the grass plate, and on the second date only 5; both nights were clear and frosty, but on the first night there was a damp West wind, and on the second a dry North wind.

On December 14th there were 86 drops below the grass plate, and the sky was clear; on the 15th 12 drops only, and the sky cloudy. The minimum was 28° on both nights. Evidently the surface of the grass was warmer than the air on the second night, or the dew would have been frozen and retained on the plate, as on the first night.

On December 16th there was nothing on the grass plate, but 8 drops on the 5 foot plate. The explanation is that the radiation was sufficient to cool below dew-point the isolated plate, but not the plate in proximity to the warm earth.

On December 29th, and January 2nd and 8rd, it froze hard day and night; but the plates put out on the grass had condensed on their under-surfaces 86, 52 and 41 drops. Other cases of the same sort are March 8rd and 4th. Evidently such frosts as occur in England do not prevent the aqueous vapour of the earth from rising.

On January 31st there was nothing on the raised plate, 2 drops on the upper side of the grass plate, and nothing underneath. Probably there had been a very light rain, and the light wind had not been able to get at the plate on the ground to dry it, though it had dried the raised plate.

There were fourteen nights on which no dew was found on the grass plates; but the weather on all was very unfavourable to the formation of dew, and they therefore afford no reason for supposing that the earth did not give off vapour as usual.

I have made out nothing new from the observations for humidity.

I regret that I did not begin earlier in India, or had not further time for observations. I have given those made in the Pulney Hills merely to show how heavy the dew is in the Tropics. The place where they were taken is a hill plateau, rising abruptly to a height of a mile and a quarter above the plains, and surrounded with magnificent precipices, some of them 2,000 feet high. The top is undulating and hilly, covered with grass, with little forest but with some lovely waterfalls and hill scenery. Beside an artificial lake three miles round, a sanatorium has been established there, with a delightful

climate in summer and frosty nights in winter. The dew at times is excessive. Temperature has a great deal to do with this, the change between day and night in winter being often 45° or more. I have several times found the thermometer 28° at night, and above 75° in the day, and nearly the whole of this change occurs between sunset and eight o'clock. The feeling is like entering an ice house. I inadvertently tore up my notes on temperature after using them for my official report on work in the Pulney Hills, and so have to leave the record incomplete.

The observations show how much wind interferes with dew, and the entries of March 18th and 16th are instructive, the plates having been heavily dewed, though placed on bare ground. So also are those of February 6th and 19th March, showing that though the soil had been drying up, without rain to speak of, for a month and a half, the amount of vapour given off by it was nearly the same.

NOTE BY THE AUTHOR.—The plates were exposed on the grass, there was, therefore, no circulation of air under them. The manner in which the bottle was closed was sufficient to prevent outside moisture from being deposited inside, which was all that was required. No iron or dry wood was used. The maximum and minimum temperatures are given for every day, though the observations were not made to discuss the effects of temperature or other points sufficiently investigated long ago. A paper regarding most of the points referred to in my notes was published (I believe) by Mr. Aitken a month or more before mine was sent to the Society, and Wells' theory was therefore modified from the prior date.

DISCUSSION.

The Hon. F. A. R. RUSSELL said that the author had omitted to state how close to the grass the plates were placed, and much would depend on the freedom of circulation of air between the plates and the ground. The experiments made by the author did not appear to establish any conclusion, for causes of error were not sufficiently guarded against, and same of the terms used were not convenient. For instance, by "exhalation" and "exudation" we may probably understand "evaporation." There were, no doubt, great differences in the manner in which dew deposited itself on different occasions, and the same might be remarked in rimy frosts. Quite recently he had observed, after one severe frost, that the rime, instead of being formed mainly on the upper surfaces of leaves, twigs, &c., was very much thicker on the under surfaces, and he could not say for certain what circumstances brought this change about, but probably owing to the atmospheric condition and fog overhead the radiation, after a fog came on, had been more intense towards the hard frozen ground than towards the sky. It is remarkable how decidedly rime usually grows on the windward side of any object, and the lightest air is sufficient to cause the fine needles to form abundantly on the side from which it blows. The author's experiment with the plant in the bottle seemed to be vitiated by the manner in which the bottle was imperfectly closed with leaves. "Exudation" was out of the question where iron and dry wood became covered with dew. However, these observations should be followed up, especially with regard to the deposition on plants, and might lead to results of some value.

Mr. WHIFFLE thought the paper did not contribute much to our knowledge of the formation of dew.

Mr. INWARDS said that it was to be regretted that the author had not tried the experiment of placing one plate on the top of another and larger one, so as to ascertain whether any moisture was collected on the under side of the top plate, from which any moisture issuing from the soil might be supposed to be effectually cut off.

Mr. SYMONS said that he had never studied the formation of dew, but he believed the maximum amount of dew which could be collected from one night's deposition was 0.15 in. This paper raised one subject which was frequently lost sight of when the question of dew was under consideration, viz. the evaporation from the earth. This point had been carefully thought out nearly half a century since by the Rev. L. Jenyns (now Rev. L. Blomefield) in sections 219 to 227 of his *Observations in Meteorology*, which it would be well to read along with Col. Badgely's paper.

Mr. C. HARDING inquired whether Mr. Dines could give them any information concerning the experiments on the formation of dew made by his father, the late Mr. George Dines. He believed Mr. G. Dines had said that he often found much more dew deposited on the under side of a flat piece of wood raised about 4 inches above the ground than on its upper surface. It was a pity the author of this paper had ignored temperature, as the results would doubtless be affected by this factor. He considered further experiments necessary before any modification of Wells' theory could be established.

Mr. W. H. DINES said he was afraid he could not give much information concerning his father's experiments, but so far as he recollected the conclusions his father came to were that a still night was most favourable for the formation of dew, with a high temperature during the day and a low night temperature. The board referred to by Mr. Harding was used for exposing thermometers in connection with some experiments to ascertain the amount of terrestrial radiation. It was about 6 ins. from the ground. His father had found that the readings of the thermometers underneath the board were sometimes much lower than the readings of those on the top of the board.

Mr. M. JACKSON said that he had noticed that the deposition of dew was generally greater after a series of heavy rains, when the earth was thoroughly soaked, than it was in dry weather, and he therefore was inclined to think that more dew was derived from the ground than from the air above it.

Mr. MILLER said that several years ago he had conducted a series of experiments upon the amount of evaporation from various soils and plants, the results of which were embodied in an essay which was to be found in the Library of the Society. He proposed, as soon as leisure permitted, to continue these experiments further, using various films.

THE PROBLEM OF PROBABLE ERROR AS APPLIED TO METEOROLOGY.

By THOMAS WILLIAM BACKHOUSE.

(Communicated by G. J. SYMONS, F.R.S.)

[Received November 5th, 1890.—Read February 18th, 1891.]

THE average or arithmetical mean has always been accepted and used as the best rule for combining direct observations of equal precision upon *one and the same quantity*. This universal acceptance may be regarded as sufficient to justify the axiom that it gives the most probable value; for after all, as Laplace has said, the theory of probability is nothing but common sense reduced to calculation.

But what is true with regard to (for instance) measurements of some object

whose dimension is real and fixed, is not equally true as applying to measurements of different objects, the average of such measurements being an ideal quantity. A series of annual rainfalls are measurements of varying quantities, and one would expect that the ideal annual rainfall would be better expressed by the geometric mean than by the arithmetical average.

A series of numbers, of which the varying quantities for yearly rainfall are a good example, may give rise to calculations upon the likelihood of any of them recurring, or the probability of any other selected number taking place.

Arithmetically, the consideration of the probability of any quantity of rain falling is one of *differences*, that is, the chance of the occurrence of a given quantity exceeding the average would be the same as that of one less than the average by the same difference; or the chance of *twice* the yearly average rainfall would be the same as *no rain at all* in a year! But the consideration of any *proportions* of the average is the treating of that average geometrically; that is, the chance of *twice* the yearly average rainfall occurring is the same as that of *half* that quantity; the chance of three-halves the average the same as two-thirds; that of five-fourths the same as four-fifths the average; and so on.

When the *frequency* of recurrence is required, then the statement of the probable error of the average or mean, or the probable error of the components of the average or mean, must be set forth; the probable error being calculated in the ordinary way by the method of least squares.

Though the geometrical mean of itself may not, and where the components are within somewhat narrow limits will not, be of much greater precision than the arithmetical average; yet with the necessary geometric treatment of the deviations its value is enhanced and emphasised.

As illustrating the justness of the theory for the treatment of deviations geometrically, it may be cited that in *British Rainfall* for 1881, p. 18, and 1888, p. 29, there occur the statements derived from percentage calculations of a long series of yearly rainfalls at several places, that marked excesses above the average are more frequent than deficiencies—as they should be geometrically; and that the excess in the wettest year is one-and-a-half times the average, and the defect in the driest year is not more than 65 per cent. of the average—which is the same as the geometrical statement that three-halves is equally likely with two-thirds the average.

I am therefore surprised at not having seen the views of Galton on “The Geometric Mean, in Vital and Social Statistics,” and their enlargement by MacAlister entitled “The Law of the Geometric Mean,” both of which papers appear in the *Proceedings of the Royal Society*, Vol. XXIX. pp. 865-876, applied to meteorological statistics, since these gentlemen pointed out the mode and importance of their application. I have only noticed one such attempt to adapt them, and that in a case to which the principles were not really applicable, so that it was, of course, unsuccessful.

In order to show whether the application of these views is justified, there follow here some calculations on 80 years' rainfall at Sunderland (i.e. since I

commenced to observe it). Table I is thus explained : Columns (1) and (2), (5) and (8) contain the annual rainfall from 1860 to 1889 in order of time and order of amount respectively ; column (8), the logarithms of the yearly quantities ; at the bottom of columns (2) and (8) occur the arithmetical average, probable error, and " quartile " of the figures in these columns, for the whole 30, for the first 15, and for the second 15 years ; column (4) contains the natural numbers corresponding to the averages, probable errors and " quartiles " of the logarithms in column (8). Columns (7) and (8) contain the deviation of each yearly quantity and of its logarithm from their arithmetical averages for the 30 years.

The " quartile " (as Dr. MacAlister calls it, but known in some text books as " probable error of one observation ") has such a value that the number of deviations from the average greater than it is the same as the number less than it ; or, the chances are even that a deviation taken at random will be greater or less than the " quartile."

In accordance with the principle of the geometric mean the results from the logarithms are theoretically the more correct, though their collation with those derived from the ordinary average shows that in the present investigation it makes but little difference which is used.

Table II is as follows : Column (1) contains coefficients (in half units) for a suitable range ; column (2), the values of the percentage probability integral (see Table II of Merriman's *Text Book of Least Squares*, p. 187) ; column (8), this probability integral for 30 years ; columns (4) and (5), the number of times the quartile multiplied by coefficient in column (1) occur in the 30 years.

When either the quartile or probable error,¹ together with the number of observations, is given, we can readily find out by the aid of tables the proportionate number of occasions that any particular amount of rain is likely to occur on. For example, taking the results derived from the logarithms :—Below four-fifths, or above five-fourths the mean, *once in 11 years*. For the greatest deviation that has occurred in the 30 years, viz. that whose difference of logarithm from the logarithm of the geometric mean is 0.1580 (*i.e.* representing a rainfall of 86.86 inches or more, or 18.22 inches or less), *once in about 160 years*. Below half, or above twice the average, *once in about 400,000 years*.

As shown by Table II, the agreement of observed and calculated deviations is generally close, and where divergent it would seem more likely that it is by accident than by the failure of application of the process. When, however, the 30 years are divided into two groups of 15, the arithmetical averages and geometrical means of the rainfall for each differ more than an inch from the average and mean of the 30 ; whereas according to their probable errors they should be expected only to differ about two-thirds of an inch from the truer

¹ Whether the quartile or the probable error of an average be given is of little consequence, as when the number, n , of observations (supposed of equal weight) is known, one can be deduced from the other, the quartile being probable error of average $\times \sqrt{n}$.

TABLE I.

Year.	Annual Rainfall.			Year.	Annual Rainfall.	Deviations.	
		Log.				Yearly Amount.	Log.
(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)	(8.)
	Ins.	Ins.	Ins.		Ins.	Ins.	
1860	30'81	1'4887	..	1884	19'12	— 7'06	—0'1321
1861	22'26	1'3475	..	1873	20'09	— 6'09	—0'1106
1862	24'76	1'3938	..	1868	21'29	— 4'89	—0'0854
1863	25'44	1'4055	..	1861	22'26	— 3'92	—0'0661
1864	23'77	1'3760	..	1874	22'89	— 3'29	—0'0538
1865	26'05	1'4158	..	1870	22'91	— 3'27	—0'0536
1866	27'90	1'4456	..	1871	23'30	— 2'88	—0'0462
1867	23'87	1'3779	..	1889	23'43	— 2'75	—0'0438
1868	21'29	1'3282	..	1864	23'77	— 2'41	—0'0366
1869	24'25	1'3847	..	1867	23'87	— 2'31	—0'0357
1870	22'91	1'3600	..	1869	24'25	— 1'93	—0'0289
1871	23'30	1'3674	..	1862	24'76	— 1'42	—0'0198
1872	36'86	1'5666	..	1887	24'99	— 1'19	—0'0158
1873	20'09	1'3030	..	1863	25'44	— 0'74	—0'0081
1874	22'89	1'3596	..	1885	25'96	— 0'22	+0'0007
1875	27'19	1'4344	..	1865	26'05	— 0'13	+0'0022
1876	28'70	1'4579	..	1883	26'49	+ 0'31	+0'0095
1877	30'51	1'4844	..	1888	26'49	+ 0'31	+0'0095
1878	31'03	1'4918	..	1879	26'58	+ 0'40	+0'0110
1879	26'58	1'4246	..	1875	27'19	+ 1'01	+0'0208
1880	29'01	1'4625	..	1866	27'90	+ 1'72	+0'0320
1881	29'45	1'4691	..	1876	28'70	+ 2'52	+0'0443
1882	29'96	1'4765	..	1880	29'01	+ 2'83	+0'0489
1883	26'49	1'4231	..	1881	29'45	+ 3'27	+0'0555
1884	19'12	1'2815	..	1882	29'96	+ 3'78	+0'0629
1885	25'96	1'4143	..	1886	30'07	+ 3'89	+0'0645
1886	30'07	1'4781	..	1877	30'51	+ 4'33	+0'0708
1887	24'99	1'3978	..	1860	30'81	+ 4'63	+0'0751
1888	26'49	1'4231	..	1878	31'03	+ 4'85	+0'0782
1889	23'43	1'3698	..	1872	36'86	+10'68	+0'1530
For 30 years	Average ..	26'18	1'4136	25'92 ¹	¹ These are the <i>geometric means</i> . If hyperbolic logarithms, instead of common logarithms, had been used (as suggested by MacAlister's paper), the same resulting figures would have been obtained in col. (4).		
	Prob. error	±0'47	±0'0077	±0'46			
	Quartile ..	±2'56	±0'0421	{ —2'40 +2'63			
For first 15 years	Average ..	25'10	1'3947	24'81 ¹			
	Prob. error	±0'73	±0'0114	{ —0'64 +0'66			
	Quartile ..	±2'82	±0'0443	{ —2'40 +2'67			
For second 15 years	Average ..	27'27	1'4326	27'08 ¹			
	Prob. error	±0'55	±0'0095	{ —0'59 +0'60			
	Quartile ..	±2'12	±0'0368	{ —2'21 +2'39			

average or mean, which one must suppose to be given by the whole 80 years. This suggests that the rainfall is subject to a period of deficiency or excess whose law differs distinctly from that yielding the accidental variations, though it may be that the difference is not too great to be so accounted for.

The occurrence of three rainfalls in the 80 years that should occur once in 11 years shows a good agreement between theory and fact; but the circumstance that one fall has occurred deviating to such a degree from the mean

TABLE II.

Coefficient.	Probability Integral for		Number of times Quartile × Coeff. occurs by		Coefficient.	Probability Integral for		Number of times Quartile × Coeff. occurs by	
	100 years.	30 years.	Rainfall.	Logarithms.		100 years.	30 years.	Rainfall.	Logarithms.
Minus.					Plus.				
∞ to 4½	·1	·0	0	0	0 to ½	13·2	4·0	4	6
4½ " 4	·2	·1	0	0	½ " 1	11·8	3·5	2	1
4 " 3½	·6	·2	0	0	1 " 1½	9·4	2·8	3	4
3½ " 3	1·2	·4	0	1	1½ " 2	6·7	2·0	4	4
3 " 2½	2·5	·7	1	1	2 " 2½	4·3	1·3	0	0
2½ " 2	4·3	1·3	1	1	2½ " 3	2·5	·7	0	0
2 " 1½	6·7	2·0	2	1	3 " 3½	1·2	·4	0	0
1½ " 1	9·4	2·8	4	4	3½ " 4	·6	·2	0	1
1 " ½	11·8	3·5	4	3	4 " 4½	·2	·1	1	0
½ " 0	13·2	4·0	4	3	4½ " ∞	·1	·0	0	0
					Totals	100	30	30	30

as should only happen accidentally once in 160 years shows either that the theory is only partially applicable,¹ or else that that fall was of an exceptional nature, such as cannot be expected to recur (at Sunderland) in the lifetime of any one now living.

It is obvious that the theory is not applicable to the case of *daily* rainfall, for it can only apply in cases in which the most frequently recurring numbers are those nearest to the average; and in the case of *daily* rainfall the most frequent numbers are the least possible, namely 0·00. For the same, but weakened, reason the formulæ will not apply to *weekly* rainfall, because in this also 0·00 is not an infrequent amount, though the failure of applicability is less obvious in this case. In the totals for *monthly* rain 0·00 rarely, if ever, occurs; and therefore there is more likelihood of the formulæ applying; and so as we increase the period the greater is the chance of applicability of the formulæ, till in the case of *yearly* rain, it might fairly be expected to apply. The present investigation is therefore undertaken to show whether the probability rules do apply or not to *yearly* rain. It would seem that they are very fairly applicable. In all cases where they are found not to apply, there must be some law or laws which prevent their application; and it is the province of Meteorology to find out what such laws are.

¹ This paper having been submitted to Dr. MacAlister, he writes as follows on this point: "I think your remark, 'that the theory is only partially applicable' is probably right. Where there is a likelihood of an undulatory period in the rainfalls, you would have to have a total number of observations considerably greater than that of one or two periods before you could expect the theory to accord well with fact,"

DISCUSSION.

Mr. BLANFORD said that Mr. Backhouse's paper was of importance, because it afforded us occasion to clarify our ideas as to the meaning of different kinds of mean values, and therefore of their applicability under different circumstances. The geometric mean to which the author had drawn attention might in many cases express more accurately than the ordinary average (or arithmetical mean) the most probable rainfall of any given future year; but it could by no means be substituted for that average in dealing with most of those problems that take the average rainfall as one of their data, such as all questions of water supply, and in relation to agriculture, drainage, &c. The arithmetical mean expresses that quantity which, if repeated regularly year after year, would, in the course of a great many years, yield the same total as the sum of the actual variable rainfalls of those years. Here the geometric mean would be out of place. Mr. Backhouse stated that it was found in the case of British rainfall "that the excess in the wettest year is one and a half times the average, and the defect in the driest year is not more than 65 per cent. of the average—which is the same as the geometric statement that three seconds is equally likely with two-thirds the average." There seems to be a little apparent inconsistency in these alternative statements, but the meaning is probably that a rainfall of 65 per cent. of the average (not a deficiency of 65 per cent.) is as likely as one of 150 per cent.; or in general terms that the rainfall of the driest year bears the same ratio to the average as the average does to the rainfall of the wettest year. In this quotation the average referred to would seem to be the arithmetical mean. But the author's remark that it illustrates the justness of the theory would be valid only on the supposition that it is the geometrical mean. It appeared on the evidence of several Indian stations with a very variable rainfall that the fall of the driest year bore a smaller ratio to the average (arithmetical mean) than that average does to the rainfall of the wettest year.

Mr. DINES did not think it would be advisable to use the geometrical instead of the arithmetical mean for the purpose of obtaining the average rainfall, but he thought the paper was a valuable one, and that the thanks of the Society were due to Mr. Backhouse for bringing the subject forward. If the methods indicated in the paper were more generally used, many errors would be avoided, and many curious theories would never be started; for a theory was sometimes based on differences in the values of averages, when a careful study of the theory of probability would show beforehand that such differences would be almost certain to occur.

THE GREAT FROST OF 1890-1891.

By CHARLES HARDING, F.R.Met.Soc.

[Read February 18th, 1891.]

THIS paper has been prepared at the request of the Council, and although willing to assist in the work of the Society with the hope of extending its sphere of usefulness, I cannot help feeling that some apology is necessary from me as my previous paper¹ was read so recently.

The most striking feature of the frost through which we have just passed is the very prolonged period of cold, and the very low day temperatures which were experienced throughout. There are many frosts, even of recent years, in which the temperature has fallen much lower—that is, in which the frost has been more intense; and there have also been frosts within the last few years which have been more general over the whole country; but, so far as the southern portion of England is concerned, there does not seem during the last century to have been any such prolonged period of frost as that of 1890-91.

The period dealt with is that from November 25th, 1890, to January 22nd, 1891; but before treating of that period it will be well to remind the Fellows of the very sharp frost which occurred in many parts of the country at the end of October; the shade thermometer at Greenwich registering $24^{\circ}7$, which is lower than any previous record in October during the last half century. This was followed by a spell of wet and mild weather which continued until the last week of November, when the whole country was suddenly plunged into mid-winter, severe frost and snowstorms being experienced in all parts of our islands, whilst very intense cold occurred at some of our southern coast stations. In parts of Kent and Surrey the thermometer in the screen fell almost to zero (0°), and even at Jersey it registered 16° . At Greenwich the shade temperature on the 29th fell to $18^{\circ}8$, which is the lowest reading recorded in November during the last 100 years, whilst in 20 winters during the last 40 years the thermometer has not fallen as low.

The material used by me has been obtained almost entirely from the Stations of the Meteorological Office and from those of the Royal Meteorological Society, and no temperatures are quoted which are in any way questionable or doubtful, and all the values are from thermometers exposed in authorised screens.

Fig. 1^a (p. 108) has been drawn entirely from the stations used by the

¹ "The Cold Period at the beginning of March 1890." *Quarterly Journal*, Vol. XVI. p. 152.

^a Figs. 1, 2 and 8 are reproduced from the *Journal of the Royal Agricultural Society*, March 31st, 1891, by permission of the Council of that Society.—Ed.

Meteorological Office in the compilation of its *Weekly Weather Report*, some of the results being supplied to the Office by the Royal Meteorological Society, and some by the Scottish Meteorological Society. In all, the returns from 77 stations have been used in the preparation of this diagram. The means have been obtained from the means of the maximum and minimum readings, and give the mean temperature for the whole period of 59 days, from November 25th, 1890, to January 22nd, 1891. Isotherms have been drawn for each 2° . It will be seen that a very large portion of the South-east of England had a mean temperature for the whole period below 80° , whilst at Cambridge the mean was $28^{\circ}\cdot5$, and at Hillington in Norfolk it was $28^{\circ}\cdot6$. The whole of the Midlands and a very large part of the Southern and South-western Districts of England had a mean temperature below the freezing point; whilst at sea-side stations on the Coast of Kent, Sussex, and Hampshire, the mean was only 32° .

This chart shows very clearly the great difference of temperature between various parts of the United Kingdom for the period of the frost. The warmest weather occurred in the extreme north and west of our Islands, and the exceptionally high temperature which prevailed over Scotland is quite phenomenal. In the extreme North of Scotland as well as in the West of Ireland the mean was 10° higher than in the South-east of England.

To secure accuracy in drawing the isotherms, the means given on the chart have been corrected for height above sea-level by allowing 1° decrease for every 300 feet, but no correction has been applied to the means given in the Tables.

Fig. 2 shows the deficiency of the means from the average value for the period, obtained from 20 years' observations. The greatest difference from the average at any of the Meteorological Office stations was $10^{\circ}\cdot6$ at Strathfield Turgiss, whilst a large part of the country in the Southern Midlands and the South of England had the mean temperature for the whole period of 59 days as much as 10° or more below the average. In the North of England however the deficiency did not amount to 5° , and in the extreme North of Scotland it was less than 1° .

The following Tables contain observations from the Royal Meteorological Society's Stations and from all the Weekly Weather Report Stations of the Meteorological Office. They give certain details which will serve to test the severity of the frost. The stations are grouped together in districts in accordance with the system adopted by the Meteorological Office, which is also followed by the Society in the *Meteorological Record*. The whole period of the frost from November 25th, 1890, to January 22nd, 1891, is dealt with for each station. In the body of the Table N. represents November, D. December, and J. January.

The following are a few of the most salient features gathered from the accompanying Tables :—

MEAN MAXIMUM TEMPERATURE.

Highest.

$46^{\circ}\cdot7$ at Valencia, in S.W. of Ireland.	$45^{\circ}\cdot1$ at Roche's Point.
$45^{\circ}\cdot1$ „ Scilly.	$48^{\circ}\cdot1$ „ Stornoway.
$42^{\circ}\cdot5$ „ Sumburgh Head.	$42^{\circ}\cdot5$ „ Laudale.

TABLE I.—AIR TEMPERATURES, NOVEMBER 25TH, 1890, TO JANUARY 22ND, 1891 (59 DAYS).

Station.	Whole Period.				Minimum.				Maximum.									
	Mean Max.	Mean Min.	Mean of Max. and Min.	Difference from Average.	Absolute.		Below 10°. No. of Days.	Below 20° (including below 10°). No. of Days.	No. of Days.	32° or below.		Absolute.	32° or below.		Lowest Day.	40° and above. No. of Days.		
					Date.	Days.				Date.	Days.		Date.	Days.				
SCOTLAND, N.																		
Sumburgh Head	42.5	36.2	39.4	0.5	27	J. 21	..	..	9	3	J. 4-6	53	D. 1	1	J. 21	32	J. 21	51
Stornoway	43.1	34.1	38.6	0.7	25	J. 21 & 22	..	..	22	5	D. 6-10	53	N. 30, D. 1	..	..	34	J. 21	51
Wick	41.9	34.1	38.0	0.9	20	J. 7	..	..	21	8	J. 3-10	54	D. 1	..	..	34	J. 22	41
Laing	38.5	27.9	33.2	4.2	9	J. 7	1	5	47	14	D. 16-29	55.5	N. 30, D. 1	5	D. 6 & 7	28	N. 27, J. 7	19
Glencarron	39.3	29.8	34.6	2.6	18.8	J. 22	..	..	43	10	D. 31-J. 9	52.1	D. 1	1	D. 17	32	D. 17	25
Fort Augustus ..	40.7	30.8	35.8	2.6	18.0	N. 27, J. 22	..	2	37	9	J. 2-J. 10	53.9	D. 2	2	N. 27, D. 10	31	N. 27	31
Fort William	41.6	33.0	37.3	1.7	22.0	N. 27	..	..	26	5	D. 6-10	53.1	D. 1	2	N. 27 & 18	29	N. 27	34
SCOTLAND, E.																		
Mairn	40.7	30.4	35.6	2.3	19	N. 27	..	1	37	6	D. 6-11	57	D. 1	..	..	33	D. 7	29
Aberdeen	39.8	32.3	36.1	1.4	15	D. 22	..	1	28	7	D. 19-25	55	D. 1	6	N. 27 & 28	31	D. 21, J. 7	30
Braemar	36.4	27.4	31.9	2.3	8.0	J. 7	2	10	46	18	D. 24-J. 10	51.8	D. 1	11	N. 26-28	24.8	N. 27	8
Ochiltre	39.2	29.1	34.2	2.9	18	J. 9	..	2	43	14	D. 16-29	52	D. 1, J. 12	5	D. 18 & 19	28	D. 19	23
Leith	40.5	31.1	35.8	2.2	20.8	J. 8	..	..	35	8	D. 18-25	56.5	D. 1	1	D. 13	31.6	D. 13	30
Marchmont	37.5	28.6	33.1	2.8	16	J. 18	..	5	43	8	J. 15-22	50	D. 1	6	D. 13 & 14	29	D. 14	15
SCOTLAND, W.																		
Landale	42.5	33.4	38.0	1.9	22.7	J. 21	..	..	22	4	D. 16-19	57.6	D. 1	..	..	32.3	N. 27	38
Glasgow	40.6	30.7	35.2	2.2	22.3	N. 27	..	..	20	7	J. 4-10	51.0	D. 1	1	D. 19	30.4	D. 19	27

TABLE I.—AIR TEMPERATURES, NOVEMBER 25TH, 1890, TO JANUARY 22ND, 1891 (59 DAYS).—Continued.

Station.	Whole Period.			Minimum.				Maximum.											
	Mean Max.	Mean Min.	Difference from Mean of Max. and Min.	Absolute.		Below 10°. No. of Days.	Below 20° (including below 10°). No. of Days.	32° or below.		Absolute.		32° or below.		Lowest Day.	40° and above. No. of Days.				
					Date.			No. of Days.	Lowest conse- cutive period and limiting dates.	No. of Days.	Date.	Days.	Date.						
ENGLAND, N.W.—Continued.																			
Aysgarth .....	..	..	..	°	J. 18	2	11	51	20	D. 6-25	47°5	°	D. 1, J. 13	14	3	D. 12-14	25°8	D. 13	10
Stonyhurst	36°5	28°0	32°3	— 6°3	J. 19	..	7	45	15	D. 18-J. 1	46°1	J. 20	8	3	3	D. 18-20	27°1	D. 14	13
Blackpool	36°6	29°1	32°9	— 7°9	D. 22	..	4	39	15	D. 12-J. 6	44°2	D. 1 & 3	7	4	4	D. 18-21	27°6	D. 12, 19	16
Bolton .....	..	..	..	14°9	J. 18	..	7	47	18	D. 9-26	43°4	D. 1	9	4	4	D. 18-21	25°5	D. 20	10
Manchester	35°9	28°0	32°0	— 7°1	D. 20	..	6	45	13	D. 11-23	45°3	D. 5	9	3	3	J. 17-19	27°2	D. 13	9
Liverpool	37°1	29°3	33°2	— 7°0	D. 21	..	3	41	15	D. 12-26	48°	J. 22	9	5	5	D. 18-22	26°	J. 20	19
Northwich .....	..	..	..	5°0	D. 22	1	9	56	47	D. 7-J. 22	45°0	J. 12 & 20	4	..	..	..	29°0	D. 12	15
Llandudno	40°3	31°7	36°0	— 5°9	D. 20, 21, J. 13	..	..	29	11	D. 12-22	51°7	D. 1	2	..	..	..	30°0	D. 20	30
Holyhead	41°9	34°5	38°2	— 5°1	D. 22, 31 J. 1, 18	..	..	22	11	D. 13-23	51°	D. 1	0	..	..	..	34°	D. 28	39
ENGLAND, E.																			
Hillington	33°7	22°9	28°3	— 9°6	J. 18	6	19	53	26	D. 9-J. 3	44°1	D. 4	20	6	6	J. 6-11	26°3	J. 10	5
Yarmouth	35°2	27°9	31°6	— 7°3	J. 11	..	1	47	29	D. 15-J. 12	43°	D. 3 & 4	15	4	4	J. 16-19	28°	D. 29	8
Somerleyton .....	..	..	..	4°1	J. 10	2	12	48	16	D. 10-25	44°2	D. 3	11	3	3	J. 8-10	28°2	D. 29	13
Geldeston	35°6	24°0	29°8	— 9°1	J. 11	2	15	52	26	D. 9-J. 3	44°	D. 9	11	2	2	N. 27 & 28 D. 29 & 30	28°6	D. 30	12
Lowestoft .....	..	..	..	13°2	J. 11	..	2	43	9	J. 14-22	50°3	N. 25	4	4	4	J. 10-11	27°3	D. 30	17
Cambridge	34°0	22°3	28°2	— 10°0	D. 22	3	21	57	48	D. 6-J. 22	44°	D. 4, J. 20	25	11	11	D. 13-23 N. 26-30	25°8	D. 22	8
Great Thurlow .....	..	..	..	5°0	D. 22	3	19	54	37	D. 7-J. 12	42°6	D. 4	27	5	5	D. 15-19 J. 6-10	25°9	D. 30	4

TABLE I.—AIR TEMPERATURES, NOVEMBER 25TH, 1890, TO JANUARY 22ND, 1891 (59 DAYS).—Continued.

Station.	Whole Period.			Minimum.			Maximum.						
	Mean Max.	Mean Min.	Difference from Min.	Absolute.	32° or below.		Absolute.	32° or below.		Lowest Day.			
					No. of Days.	Longest consecutive period and limiting dates.		No. of Days.	Longest consecutive period and limiting dates.				
	Date.	Below 10°. No. of Days.	Below 20° (including below 10°). No. of Days.		Days.	Date.		Days.	Date.				
MID. COUNTRIES—Continued.											40° and above. No. of Days.		
Burghill	0	0	0	6.1	D. 22	2	11	52	38	D. 7-J. 13	46.6	J. 20	D. 30
Great Malvern.....	..	..	..	16.6	J. 19	..	5	50	28	D. 7-J. 3	44.9	J. 22	D. 31
Hereford	35.4	25.1	30.3	8.3	..	..	..	..	46	D. 7-J. 21	45.7	J. 22	..
Ross .....	..	..	..	7.3	J. 19	2	11	53	46	D. 7-J. 21	45.7	J. 22	D. 30
Cheltenham .....	..	..	..	5.5	D. 22	2	14	54	47	D. 6-J. 21	45.2	J. 20	J. 18
Oxford	33.8	23.9	28.9	10.2	D. 23	2	12	54	38	D. 7-J. 13	43	D. 4, J. 22	D. 13 & 22
Girencester	34.7	22.6	28.7	9.9	D. 23	2	15	55	38	D. 7-J. 13	44	J. 22	D. 30
Berkhamsted .....	..	..	..	11.1	D. 22	..	16	53	37	D. 7-J. 12	42.9	J. 20 & 21	D. 30
ENGLAND, &c.													
London (Old Street, &c.) .....	..	..	..	17.2	D. 20	..	1	48	35	D. 10-J. 13	44.9	J. 20	D. 30
" Brixton	35.2	25.6	30.4	8.8	D. 22, J. 11	..	8	52	35	D. 10-J. 13	45	D. 4	J. 11
" Camden Square .....	..	..	..	..	..	..	..	..	..	..	..	..	..
Kew Observatory .....	..	..	..	10.7	D. 23	..	8	52	36	D. 9-J. 13	43.8	D. 4	D. 14
West Norwood .....	..	..	..	12.5	J. 10	..	13	52	34	D. 10-J. 12	44.1	J. 21	N. 28
Addiscombe .....	..	..	..	9.6	J. 10	1	20	55	38	D. 7-J. 13	44.6	J. 20	D. 30
Addington Hills .....	..	..	..	11.2	J. 10	..	18	58	47	D. 7-J. 22	43.4	J. 20	D. 30
Waddon	33.9	21.8	27.9	..	N. 29	6	23	55	38	D. 7-J. 13	44.0	J. 20	D. 14
Beddington	34.0	21.4	27.7	..	N. 28	4	24	56	47	D. 7-J. 22	44.0	J. 20	D. 14
Kenley	33.3	23.1	28.2	..	N. 29	2	20	53	28	D. 7-J. 3	43.5	J. 20	D. 30
Greenwich	33.5	25.0	29.3	9.5	J. 10	..	10	52	35	D. 10-J. 13	43.8	J. 20	D. 22

¹ Worked up from Climatological Series of Observations and comparable with others in Table.² Difference from Mean of 60 years (1814 to 1873).

TABLE I.—AIR TEMPERATURES, NOVEMBER 25TH, 1890, TO JANUARY 22ND, 1891 (59 DAYS).—Continued.

Station.	Whole Period.				Minimum.				Maximum.									
	Mean Max.	Mean Min.	Mean of Max. and Min.	Difference from Average.	Absolute.		Below 10°. No. of Days.	Below 20° (including below 10°). No. of Days.	32° or below.		Absolute.		32° or below.		Lowest Day.	40° and above. No. of Days.		
					Date.	Below 10°. No. of Days.			Longest consecutive period and limiting dates.	Date.	Below 20° (including below 10°). No. of Days.	Longest consecutive period and limiting dates.	Date.	Below 20° (including below 10°). No. of Days.			Longest consecutive period and limiting dates.	Date.
ENGLAND, S.—Continued.																		
Chatham	°	°	°	°	° 13	..	52	D. 7-J. 12	°	J. 20	22	4	D. 14-18	°	D. 30	10		
Reading	°	°	°	°	° 9'0	1	57	D. 7-J. 12	44	D. 4	36	11	D. 10-20	21'2	D. 14	2		
Tunbridge Wells	°	°	°	°	° 8'7	1	55	D. 7-J. 13	41'0	J. 20	23	5	D. 15-19	23'9	D. 30	7		
Stratfield Turgiss	34.2	22.4	28.3	-10.6	7.5	1	52	D. 8-J. 13	43'2	D. 5	23	5	D. 11-17	22'5	D. 22	10		
Stowell	34.7	24.7	29.7	-10.1	11.9	..	52	D. 7-26	46'9	D. 4	19	3	Various	25'1	D. 30	9		
Harestock	°	°	°	°	° 11'0	..	53	D. 7-J. 3	44'2	J. 21	21	4	D. 14-17	24'4	N. 28	7		
Parkstone	°	°	°	°	° 14'3	..	54	D. 7-J. 12	46	J. 22	15	3	D. 28-30	25'6	N. 28	11		
Margate.....	°	°	°	°	° 15'6	..	50	J. 5-22	43'6	D. 4	13	2	Various	26'4	D. 30	7		
Dungeness	37.1	26.7	31.9	-9.2	12	8	48	D. 23-J. 13	45	J. 22	12	2	..	28	D. 30, J. 9	20		
Bexhill	°	°	°	°	° 14'9	..	50	D. 10-J. 1	43'2	J. 13	12	3	D. 28-30	26'2	D. 30	13		
Hastings	36.1	28.1	32.1	-8.6	16.3	..	46	D. 10-19	42'4	J. 3	12	3	D. 28-30	27'1	D. 30	15		
Eastbourne	°	°	°	°	° 17	..	43	D. 22-31	50	N. 26	5	2	J. 17-19	27'6	D. 30	27		
Brighton	°	°	°	°	° 17'5	..	48	D. 10-20	49'4	N. 25	9	3	D. 18-20	26'4	D. 30	17		
Worthing	°	°	°	°	° 14'9	..	53	D. 8-J. 13	44'0	J. 12	12	3	D. 28-30	26'7	D. 30	15		
Portsmouth	°	°	°	°	° 16'5	..	49	D. 8-J. 3	45'5	J. 20	11	3	D. 28-30	27'4	D. 30	16		
Southampton	36.2	25.7	31.0	-8.4	16	..	51	D. 7-J. 3	46'1	J. 22	8	2	D. 29 & 30	26'6	N. 28	12		
Ventnor	°	°	°	°	° 20'7	..	32	N. 26-30	45'7	D. 3	3	..	J. 6 & 7	25'7	N. 28	24		
							5	D. 15-19	45'7	D. 3	3	..	..	25'7	N. 28	24

TABLE I.—AIR TEMPERATURES, NOVEMBER 25TH, 1890, TO JANUARY 22ND, 1891 (59 DAYS).—Continued.

Station.	Whole Period.			Minimum.				Maximum.					
	Mean Max.	Mean Min.	Difference from Average.	Absolute.		No. of Days.	32° or below.		Absolute.	32° or below.		Lowest Day.	
				Below 10°.	Below 20° (including below 10°).		No. of Days.	Longest consecutive period and limiting dates.		Date.	No. of Days.		Longest consecutive period and limiting dates.
ENGLAND, S.—Continued.													
Totland Bay, I. W.....	°	°	°	°	19	3	47	D. 31, J. 18 & 19	24	D. 11-J. 3	°	°	
Hurst Castle	37.6	27.8	32.7	-8.7	19	2	43	D. 15, J. 20	16	J. 5-20	45	27	
Weymouth	°	°	°	°	19.0	1	37	J. 18	8	D. 14-21 J. 5-12	46.0	28	
Roussell	°	°	°	°	15.3	7	46	J. 18	15	D. 11-25	44.0	28.0	
ENGLAND, S.W.													
Aberystwith	°	°	°	°	17.9	2	35	J. 18	11	D. 12-22	48.2	°	
Llandoverly	36.9	24.0	30.5	-9.7	7	16	53	J. 18	42	D. 12-J. 22	46	27	
Carmarthen	°	°	°	°	13.5	8	45	J. 18	12	D. 11-22	47.0	28	
Pembroke	41.3	33.1	37.2	-5.7	19	5	26	D. 31	6	D. 27-J. 1	51	32	
Weston-super-Mare	°	°	°	°	15.0	5	47	J. 19	20	D. 7-26	46.0	31	
Ilfracombe	°	°	°	°	21.3	0	24	D. 31	7	D. 12-18	49.8	27.2	
Arlington	37.5	27.3	32.4	-8.0	°	°	°	°	°	°	°	29.9	
South Molton	°	°	°	°	9.5	11	47	J. 19	22	D. 12-J. 2	47.5	°	
Cullompton	36.9	26.0	31.5	-9.5	10.1	11	49	J. 19	17	D. 28-J. 13	47.0	27.0	
Bude	°	°	°	°	17.6	4	40	J. 8	11	J. 5-15	47.0	27.1	
Brampford Speke.....	°	°	°	°	12.7	6	47	J. 19	15	D. 12-26	46.1	27.5	
Exeter	°	°	°	°	13.0	4	45	J. 19	15	D. 12-26	48.7	27.0	

TABLE I.—AIR TEMPERATURES, NOVEMBER 25TH, 1890, TO JANUARY 22ND, 1891 (59 DAYS).—Continued.

Station.	Whole Period.				Minimum.				Maximum.												
	Mean Max.	Mean Min.	Mean of Max. and Min.	Difference from Average.	Absolute.		32° or below.		Absolute.	32° or below.		Lowest Day.									
					Date.	Below 10° No. of Days.	Below 20° (including below 10°) No. of Days.	No. of Days.		Date.	No. of Days.										
													Longest consecutive period and limiting dates.	Days.	Longest consecutive period and limiting dates.	Days.					
ENGLAND, S.W.—Continued.																					
Princetown	0	0	0	0	12°4	J. 18	17	52	22	D. 12-J. 2	47°3	D. 2	16	4	N. 26-29 D. 28-31	24°7	D. 30	16			
Ashburton .....	..	..	..	..	18°6	J. 19	3	40	9	J. 5-13	47°9	J. 3	7	3	D. 28-30	25°6	D. 30	26
Sidmouth .....	..	..	..	..	18°0	J. 19	3	42	11	D. 12-22	48°3	J. 22	7	2	D. 29 & 30 J. 17 & 18	27°0	D. 30	26
P'abbacombe .....	..	..	..	..	14°0	J. 19	2	31	5	N. 26-30 D. 27-31	48°9	J. 22	3	..	..	29°1	D. 30	30
Falmouth	42°1	32°3	37°2	-6°8	22°3	N. 29	..	27	5	N. 26-30 D. 28-31	49°9	J. 22	2	..	..	31°6	D. 30	42	
Plymouth	40°5	30°2	35°4	-7°3	19°8	J. 19	1	37	9	J. 5-13	49°5	J. 22	3	Var.	..	29°5	D. 30	37			
Prawle Point	40°9	31°3	36°1	-6°5	19	N. 27	1	31	9	J. 5-13	49	J. 1	4	1	..	28	N. 29	36			
CHANNEL ISLANDS.																					
Silly	45°1	38°1	41°6	-5°2	29	N 28, J. 17 & 18	..	13	4	N. 24-30 J. 17-20	51	D. 10	..	..	..	35	J. 6	55
Guernsey .....	..	..	..	..	25°5	N. 29	..	18	5	N. 27-D. 1	48°7	J. 1	0	..	..	33°7	J. 17	33
Jersey	41°2	31°2	36°3	-6°9	12°2	J. 18	3	32	9	D. 24-J. 1	50	J. 22	..	..	..	37°3	D. 16	34
IRELAND, N.																					
Malin Head	42°8	35°8	39°3	-1°2	30	J. 8 & 18	..	11	2	N. 27 & 28 D. 17 & 18 J. 7 & 8 J. 18 & 19	53	N. 30, D. 1	..	..	..	35	J. 7	46

MEAN MAXIMUM TEMPERATURE—Continued from p. 94.

Lowest.

° 33·5 at Greenwich.	° 33·7 at Hillington.
33·8 „ Rothamsted.	33·8 „ Oxford.
But going outside of the Meteorological Office stations	
	33·3 at Kenley.

MEAN MINIMUM TEMPERATURE.

Highest.

° 38·1 at Scilly	° 36·2 at Sumburgh Head.
36·1 „ Valencia.	

Lowest.

° 22·3 at Cambridge.	° 22·4 at Strathfield Turgiss.
But going outside of the Meteorological Office returns	
21·4 at Beddington.	21·8 at Waddon.

Mr. Symons, in his *Meteorological Magazine*, gives the mean minima for several European Stations from December 18th to January 22nd, and completing this for a few stations for the period dealt with in this paper, we get :—

° 18·6 at Brussels.	° 21·1 at Paris.
32·7 at Biarritz.	38·9 at Rome.

The mean minimum at Biarritz being 0°·3 colder than at Ardrossan.

The *Absolute Minimum* occurred at different periods of the frost; it was only 27° at Sumburgh Head, and 25° at Stornoway, but it is more interesting to examine the region of the severe frost.

In England NE the coldest day was January 18th or 19th, and at Rounton the temperature fell to 0°·6 (the same temperature was also recorded at Stokesay on December 22nd, and is the lowest authentic reading during the frost).

In England N.W. the minimum occurred generally on December 20th, 22nd, or January 18th, but not in all places. The absolutely lowest reading was 5°·0 at Northwich on December 22nd.

In England E the minimum occurred generally on January 11th at the Northern stations, the lowest reading being 4°·1 at Somerleyton; whilst at the Southern stations the lowest reading occurred on December 22nd, and at Cambridge and Chelmsford the minimum was 4°.

In the Midland Counties the minimum temperature for the period was about equally divided between December 21st-23rd and January 18th or 19th. The absolutely lowest were 0°·6 at Stokesay, in Shropshire, on December 22nd, and 1° at Stamford on January 18th.

In England S. the lowest readings occurred at very different periods of the frost. In parts of Kent and Surrey as well as on the coast of Sussex and Hampshire the minimum occurred on November 28th or 29th, and at Waddon the thermometer in the screen fell to 1°·0, whilst at Beddington it fell to 2°·3. At Dungeness the thermometer fell to 12°; at Worthing and Rousdon to

15°; at Margate, Hastings, and Southampton, to 16°; at Eastbourne and Portsmouth to 17°.

At some stations the readings were below 10° in the latter part of December, and almost equally low readings occurred on January 10th-11th and 18th-19th, but the November readings in parts of Kent and Surrey were the lowest in the District for the whole period.

In England SW the minimum occurred on November 27th-29th, December 31st, and January 19th. The South-coast stations had their minimum in November, but in the greater part of the District the minimum occurred on January 19th. The absolutely lowest readings were 7° at Llandoverly, 9°·5 at South Molton, and 10°·1 at Cullompton, on January 18th or 19th.

At Scilly and the Channel Islands the minimum occurred on November 28th-29th and January 17th-18th. The lowest reading was 12°·2 at Jersey on January 18th, which is within 0°·2 as low as the lowest reading at Greenwich during the frost.

In Ireland the lowest temperature occurred at very different dates at the several stations, but at many of the coast stations it took place on November 27th or 28th. The absolutely lowest readings were 14°·8 at Brookeborough, and 15° at Kilkenny.

The column for the number of days with the minimum 32° or below shows that at Addington Hills, near Croydon, frost occurred each night with but a single exception, and at both Cambridge and Reading there were only two exceptions. At Sumburgh Head frost only occurred on 9 days, whereas at Biarritz it occurred on 81 days, and at Rome on 9 days. At Brussels there was frost each day throughout the period.

At many places in England the frost was continuous night and day for 10 days, but at coast stations in the North of Scotland it in no case lasted throughout the 24 hours.

The lowest day temperature shows that several different days were exceptionally cold. The absolutely lowest maximum day temperature was 21° at Reading on December 14th.

It is comparatively easy to explain the great difference between the weather over England and that in either Scotland or Ireland. During the whole period of the frost there was a large area of high barometric pressure situated over Europe, which maintained an almost permanent position. The incoming disturbances from the Atlantic could not effect a passage into Europe, but being fended off by the European anticyclone, their centres kept well out in the Atlantic. Consequently both Ireland and Scotland felt the warming influence of these disturbances, although the weather remained comparatively quiet, whilst England, and especially its eastern parts, was not at all affected by them.

The severity of the cold spell at the end of November is distinctly traceable to a long arm of easterly wind blowing directly over the British Islands from off the cold Continent of Europe.

The very dry character of the weather over England during the frost is also attributable to the fact that the European anticyclone embraced the southern

portion of the Kingdom, and although on two or three occasions there were some rather heavy falls of snow, the aggregate fall of snow and rain was but very trifling in comparison with the average.

Table II. is obtained from the 8 a.m. observations given in the *Daily Weather Report* of the Meteorological Office, and contains the means of the morning air temperatures for the several parts of the British Islands. The coast stations are too strongly represented for the general means to be absolutely correct, but the relative differences may be of value.

Fig. 8 shows the Greenwich shade temperatures for the whole period of the frost, also the average daily mean for the period derived from the observations of 60 years, 1814 to 1878. The temperatures used are for the civil day and will be found to differ slightly from those given in Table I.

This diagram (p. 109) shows that the mean temperature for each day was below the average with the single exception of January 18th. The marked absence of anything approaching warm days is also clearly shown.

On examination of the earth temperatures they show that the frost did not penetrate to the depth of 2 ft. below the surface of the ground in any part of England, but in many parts, especially in the south and east, the ground was frozen for several days at 1 ft. below the surface, and at 6 ins. it was frozen for nearly a month. At Hodsock Priory, Worksop, the temperature at 1 ft. did not fall below $32^{\circ}8$ throughout the period of the frost. The absolutely lowest temperature was reached on January 20th. The earth thermometer was continuously below 35° from December 21st to January 30th.

At Lowestoft the temperature at 4 ft. below the surface did not fall below $37^{\circ}9$, which was registered quite at the end of the frost, and at 2 ft. deep it did not fall below 38° . At the depth of 1 ft. the thermometer stood at 31° on January 21st, but this was the only day throughout the period with the reading down to the freezing point.

At Berkhamsted the temperature at 2 ft. below the surface did not fall below $38^{\circ}4$, the absolutely lowest temperature at this depth was on January 22nd, quite at the end of the frost. The soil at 1 ft. was frozen from January 11th to 28th, the lowest temperature was $30^{\circ}1$ on January 19th and 20th.

Mr. Mawley writes :—"The soil in the kitchen garden, and also in a border in the flower garden is frozen to the depth of 8 ins. As I was surprised to find the frost had gone no deeper, I had a piece of the lawn exposed near where the earth thermometers are situated, and there the depth of frozen soil was 7 ins. As the lowest reading here was $30^{\circ}1$ at 1 ft. and $38^{\circ}4$ at 2 ft., it seems that it takes a lower temperature than 32° to freeze soil, at all events when moderately dry as it has lately been." The test was made by Mr. Mawley on January 22nd.

At Harestock, near Winchester, the temperature at 6 ft. below the surface did not fall below 48° during the period of the frost, and it was not below 46° during December. At 4 ft. the temperature fell to 39° at the end of the frost, and at 2 ft. to $38^{\circ}8$, the lowest reading being registered on January 21st. At 1 ft. the soil was frozen from January 10th to 22nd, and the lowest temperature was $31^{\circ}1$ on January 19th. At 6 ins. the soil was frozen from

TABLE II.—MEANS OF THE 8 A.M. TEMPERATURES PUBLISHED IN THE DAILY WEATHER REPORT, NOVEMBER 25TH, 1890, TO JANUARY 22ND, 1891.

Date.	Scotland.	Ireland.	England.	British Isles.
November 25....	38	42	36	38
" 26....	35	36	32	33
" 27....	27	31	29	29
" 28....	30	31	29	30
" 29....	33	33	29	31
" 30....	43	46	31	37
December 1....	52	52	40	45
" 2....	49	50	38	43
" 3....	39	43	38	39
" 4....	39	38	42	40
" 5....	40	42	40	40
" 6....	38	41	39	39
" 7....	34	39	35	36
" 8....	36	38	36	37
" 9....	39	36	34	36
" 10....	34	35	36	35
" 11....	40	45	34	38
" 12....	38	44	31	36
" 13....	33	41	30	34
" 14....	35	42	27	33
" 15....	41	44	31	36
" 16....	37	38	31	34
" 17....	36	33	32	33
" 18....	35	41	31	35
" 19....	31	37	31	33
" 20....	35	35	29	32
" 21....	29	31	29	30
" 22....	34	43	23	31
" 23....	42	44	32	37
" 24....	35	35	32	34
" 25....	40	41	29	34
" 26....	37	35	35	35
" 27....	36	35	33	34
" 28....	36	37	32	54
" 29....	33	35	32	33
" 30....	37	36	29	32
" 31....	38	34	27	31
January 1....	39	41	36	38
" 2....	38	39	32	35
" 3....	37	39	33	35
" 4....	37	39	38	38
" 5....	33	34	31	32
" 6....	31	32	28	30
" 7....	29	29	25	27
" 8....	34	38	28	32
" 9....	33	37	32	34
" 10....	33	34	27	30
" 11....	44	43	28	35
" 12....	49	41	34	39
" 13....	44	40	39	40
" 14....	36	41	36	37
" 15....	36	39	32	35
" 16....	36	44	35	38
" 17....	33	39	27	31
" 18....	32	35	22	27
" 19....	35	38	23	30
" 20....	43	46	38	41
" 21....	30	36	34	34
" 22....	32	40	37	37
Mean 59 days.	37	39	32	35
Days with mean temp. 32° or below	9	5	35	16
Lowest daily mean	27°	20°	22°	27°
	Nov. 27	Jan. 7	Jan. 18	Jan. 7 & 18

THE GREAT FROST OF 1890 - 1891

ISOTHERMS AND VALUES
SHOWING MEAN TEMPERATURE
FOR WHOLE PERIOD

FROM
25TH NOV: 1890 TO 22ND JAN: 1891.

DEFICIENCY OF MEANS
FROM 20 YEARS' AVERAGE
IN DEGREES FAHRENHEIT
FOR WHOLE PERIOD.

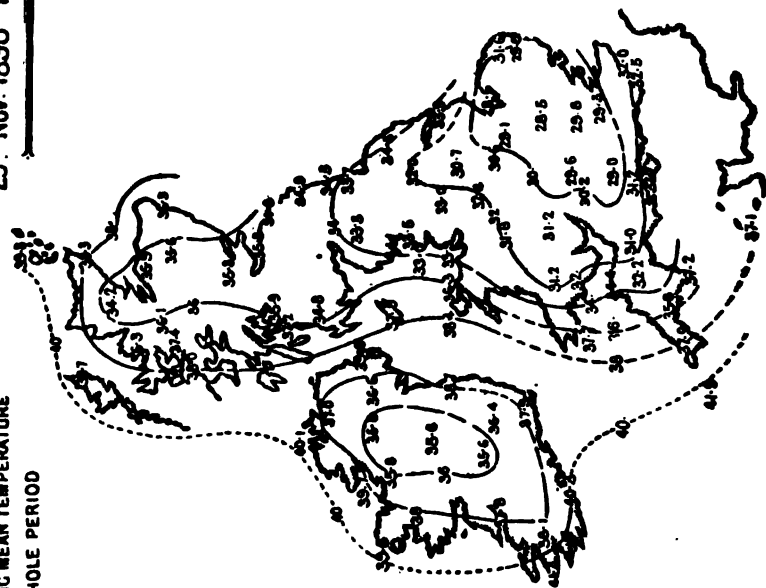


FIG. 1.



FIG. 2.

TABLE III.

SHOWING THE MEAN TEMPERATURE AND THE ANNUAL DEATH-RATE PER 1,000 OF THE TOTAL POPULATION FOR EACH WEEK IN THE THREE MONTHS NOVEMBER, DECEMBER 1890, AND JANUARY 1891, OBTAINED FROM THE REGISTRAR GENERAL'S WEEKLY RETURNS.

Weeks ending		November.				December.				January.				
		8.	15.	22.	29.	6.	13.	20.	27.	3.	10.	17.	24.	31.
Mean temperature of all England..		45°0	43°2	48°7	35°9	37°3	33°0	29°8	30°4	31°5	30°2	33°2	34°3	43°4
Death rate in 28 Great Towns of England & Wales		20°8	21°1	21°3	19°0	21°5	21°3	25°1	27°8	28°7	28°1	27°3	25°1	22°3
Mean temperature at Greenwich ..		45°2	44°5	50°0	34°3	35°3	30°6	26°9	28°1	28°6	23°2	30°9	35°3	44°2
Death rates in London—all causes		20°5	20°2	20°2	18°0	20°4	21°1	26°0	26°3	29°7	29°1	29°2	25°7	22°1
Deaths from	Years under 1	393	392	369	296	362	354	414	389	459	397	417	401	370
	1 to 5	283	257	308	266	296	304	384	333	313	358	289	297	262
	5 to 20	109	109	112	100	100	109	101	102	120	121	104	78	87
	20 to 40	222	239	226	207	205	210	257	251	236	298	296	333	206
	40 to 60	331	296	283	277	317	319	419	412	511	488	595	450	390
	60 to 80	318	343	350	300	372	391	515	602	729	705	659	615	471
	89 & above	78	73	68	81	81	100	116	142	148	138	153	138	117
	Respiratory Organs	465	465	459	375	444	487	753	806	927	991	1018	845	636
	Phthisis	153	174	184	151	189	161	203	187	182	183	216	182	136
	Dis. of Circulatory System ..	141	139	134	130	167	157	200	189	219	220	220	194	156

These figures show the very marked increase in the death rate with persons whose ages are above 40 years, also the high rate of increase in the number of deaths from diseases of the respiratory organs. It is however seen that there is a falling off in the number of the deaths before the period of the frost has ended.

December 15th to January 26th, the lowest reading was 28°·6 on January 19th.

At Stowell, in Somerset, the soil was frozen at the depth of 1 ft. only on two days, January 19th and 20th, the lowest temperature being 81°·8. The temperature was however 84°, or below it, from December 30th to January 28th.

At Southampton the temperature 4 ft. below the surface reached its minimum after the termination of the frost, the lowest reading was 89°·4 from January 27th to 30th; in December it did not fall below 42°·6. At 2 ft. it fell to 86°·2 on the last day or two of the frost. At 1 ft. the lowest temperature was 88°·8 on January 19th and 21st. At 6 ins. deep the soil was 82° or below from January 7th to 25th, the lowest reading was 27°·5 on January 19th.

At Babbacombe, on the South Coast of Devon, the temperature at 1 ft. below the surface did not fall below 84°·5, which was reached on January 21st, whilst at 6 ins. the lowest temperature was 88°·1 on January 19th.

At Greenwich the mean temperature of the earth at 8 ft. below the surface was 38°·1 for the month of January, which is 4°·0 below the average for the previous 48 years, and lower than in any month during the same period, with

the exception of February 1855, when the mean was $86^{\circ}9$. The earth at the depth of 1 in. below the surface was only frozen at noon on 15 days throughout the whole period of the frost.

The observations published in the Weekly Returns of the Registrar-General show that the temperature of the Thames water off Deptford, at 2 ft. below the surface, was continuously below 84° from December 23rd to January 23rd, a period of 82 days, while the river was blocked with ice during the greater part of the time.

The records of sea surface temperature received by the Meteorological Office from light-ships, &c. round the coasts of the British Islands show that, in November the mean sea temperature was in good agreement with the average conditions. In the English Channel the mean was about 58° , whilst it was about 48° on the West coast of Ireland and 47° on the East coast of England. In December the sea temperature was colder than the average, but the difference was very irregular. In the Hebrides the deficiency on the average was about 8° , on the West coast of Ireland about 2° or 8° , whilst in the South of Ireland the water was but very slightly colder than usual. In the English Channel the deficiency ranged from about 5° on the coast of Devon to only 1° in the Eastern half of the Channel. On the East coast of England the sea was colder by 2° or 8° , but that on the East coast of Scotland was slightly warmer than usual. A comparison of the air and sea temperature on the coasts of the British Isles shows that on the coast of Sussex the sea was 14° warmer than the air, on the coast of Norfolk 12° warmer, on the coast of Yorkshire and the North-east of England 6° warmer, off the Northeast of Scotland 8° warmer, in the Shetlands 8° warmer, in the Hebrides the temperature of the air and sea were the same, on the West coast of Ireland the sea was from 8° to 5° warmer than the air, in Cardigan Bay it was 18° warmer, and at Scilly 9° warmer.

A record of the sea temperature at Eastbourne is given by Mr. Sheward, the observation being made at the Pier Head each day at 8.80 a.m. This temperature is, however, very different from that given on board the *Royal Sovereign* Light Ship, but the conditions are not at all similar. At Eastbourne the sea is shallow, and the beach would naturally be cold under the influence of the low air temperature. The *Royal Sovereign* is in comparatively deep water, and at about six miles distant from the shore. At Eastbourne the mean sea temperature in December was $87^{\circ}8$; there was no day with the temperature above 42° , and on 7 days it was 85° or below; whilst at the *Royal Sovereign* the mean for December was $46^{\circ}8$, and the temperature was not once below 42° . At Eastbourne the mean sea temperature in January was $84^{\circ}5$, at no time did the thermometer indicate a higher reading than 88° , and 86° was not exceeded until the 28th; whilst on the 9th the temperature was 81° , which is the lowest reading observed during 7 years by Mr. Sheward. On the morning of the 11th the sea temperature at the Pier Head was 82° , and the incoming edge of the sea is reported to have been fringed with ice. At the *Royal Sovereign*, in January, the mean temperature of the water at the depth of 1 foot was 40° , and there were only 8 days during the

month with the reading below 86° , although at sunrise on January 18th and 19th the thermometer registered 81° .

The *Pilot Chart* of the North Atlantic Ocean for February, published by the United States' Hydrographic Office, gives some interesting accounts of obstruction caused to navigation owing to rivers and ports being blockaded by ice. The following is a brief abstract of the reports :—

HAMBURG, January 8th.—Since Christmas the Island of Heligoland has been cut off from all communication with the mainland, and great masses of ice are floating in the North Sea, off the mouth of the Elbe.

STETTIN, January 9th.—There is 15-inch ice in the Haff; in places it is piled up several feet high, and firmly frozen together.

KIEL, January 19th.—The Baltic, as far as it can be seen, is covered with ice.

TOULON, January 19th.—The harbour is frozen over for the first time on record.

BORDEAUX, January 19th.—A large number of vessels are ice-bound, and many vessels have gone down the river to avoid being frozen in.

LONDON, January 19th.—The ice floating on the Thames between the Bridge and Tower is so packed that all movements of vessels have entirely ceased.

LISBON, January 20th.—The River Tagus is frozen over. The Ebro is covered with 19 ins. of ice, the first since 1829.

The following statement with regard to the thickness of the ice and days of skating was kindly furnished by Colonel Wheatley, R.E., of the Office of Works :—

In Regent's Park skating commenced on December 18th, 1890, and continued till January 24th, 1891, lasting 43 days. 344,000 persons (approximately) frequented the ice during this period. On November 28th the ice was $\frac{3}{4}$ of an inch thick, and attained $1\frac{1}{2}$ in. at the end of the month, the greatest thickness of the ice was $9\frac{1}{2}$ ins. on January 20th. On January 26th the thickness varied from 6 to $7\frac{1}{2}$ ins., and the ice was flooded with water from thaw, which was very rapid, as on the 31st all ice had disappeared even from the creeks.

In St. James's Park skating commenced December 15th, 1890, and continued without interruption till January 24th, 1891, a period of 41 days. The ice was 1 inch thick at the end of November, and attained the thickness of $8\frac{1}{2}$ ins. on January 20th.

In Hyde Park skating commenced on December 25th, when the thickness of the ice varied from $2\frac{1}{2}$ to $8\frac{1}{2}$ ins., and continued till January 24th; the greatest thickness of the ice was 8 ins. on January 22nd and 23rd.

In Regent's Park the previous records show that in 1881 skating commenced on January 18th and continued till the 27th, a period of 15 days.

In St. James's Park in the Seasons of 1879-80, skating was allowed December 8rd to 12th, 17th to 19th, 24th to 27th, January 26th to February 2nd, 4th, and 5th. In the Season 1880-1 skating was allowed January 15th to 27th. There was no ice in Season 1881-2, 1882-3, 1883-4, and 1884-5. In the Season 1885-6 there was no skating, but the ice was measured on most days from December 11th to March 17th, the greatest thickness of the ice was 8 ins. In the Season 1886-7 there was skating on December 22nd and 23rd, and January 1st to 11th. In the Season 1887-8 ice was measured frequently after December 27th, whilst skating was allowed from February 29th to March 6th. In the Season 1888-9 ice was measured in January, February, and March, the greatest thickness was $2\frac{1}{2}$ ins. on February 18th, but no skating was allowed. In the Season 1889-90 ice was measured in December, January, and March, but no skating was allowed.

In Hyde Park in the Season of 1879-80 skating was allowed on December 8th to 13th, 17th to 19th, 24th to 28th, January 27th to February 2nd, and 5th, the greatest thickness of the ice was $5\frac{1}{2}$ ins. on December 27th. In the Season 1880-1 skating was allowed January 18th to 27th, and the ice attained the thickness of 6 ins. There was no ice in Seasons 1881-2, 1882-3, 1883-4, and 1884-5. In the Season 1885-6 ice was measured frequently from December 11th to March

TABLE IV.

NUMBER OF DAYS WITH THE MINIMUM TEMPERATURE 32° AND BELOW, AND BELOW 20° , AT THE ROYAL OBSERVATORY, GREENWICH, FOR THE SIX WINTER MONTHS, FROM 1841 TO 1891.

Winters.	October.		Nov.		Dec.		January.		February.		March.		Winter 6 Months.	
	32° or below.	Below 20° .	32° or below.	Below 20° .	32° or below.	Below 20° .	32° or below.	Below 20° .	32° or below.	Below 20° .	32° or below.	Below 20° .	32° or below.	Below 20° .
1841-42	..	..	9	..	12	..	25	..	9	..	3	..	58	..
1842-43	6	..	1	..	2	..	11	..	12	..	9	..	41	..
1843-44	5	..	6	..	2	..	9	1	17	..	8	..	47	1
1844-45	1	..	2	..	20	..	12	..	19	2	18	2	72	4
1845-46	1	..	5	..	7	..	4	..	6	..	6	..	29	..
1846-47	..	..	3	..	24	3	18	..	18	5	13	1	76	9
1847-48	..	..	4	..	6	..	23	1	7	..	5	..	45	1
1848-49	..	..	9	..	5	..	13	1	7	..	6	..	40	1
1849-50	1	..	6	..	14	1	24	..	3	..	13	..	61	1
1850-51	1	..	3	..	6	..	3	..	9	..	2	..	24	..
1851-52	..	..	16	..	8	..	5	..	7	..	15	..	51	..
1852-53	1	..	..	..	1	..	3	..	21	..	18	..	44	..
1853-54	1	..	7	..	20	1	8	2	10	..	10	..	56	3
1854-55	1	..	10	..	8	..	20	2	22	10	16	..	77	12
1855-56	..	..	5	..	3	..	10	..	6	..	13	..	37	..
1856-57	2	..	9	1	13	1	19	..	12	..	9	..	64	2
1857-58	..	..	3	..	4	..	17	..	22	..	14	..	60	..
1858-59	..	..	14	..	4	..	6	..	6	..	2	..	32	..
1859-60	5	..	12	..	14	3	8	..	18	..	9	..	66	3
1860-61	..	..	4	..	13	3	22	5	5	..	2	..	46	8
1861-62	..	..	8	..	7	..	11	..	5	..	4	..	35	..
1862-63	1	..	10	..	..	..	4	..	8	..	8	..	31	..
1863-64	..	..	5	..	5	..	13	2	17	..	10	..	50	2
1864-65	..	..	7	..	12	2	17	3	14	1	17	..	67	6
1865-66	..	..	3	..	2	..	6	..	10	..	11	..	32	..
1866-67	1	..	8	..	8	..	18	7	..	..	17	..	52	7
1867-68	3	..	4	..	20	..	17	..	5	..	5	..	54	..
1868-69	2	..	10	..	1	..	8	..	2	..	16	..	39	..
1869-70	4	..	8	..	11	..	12	1	15	1	13	..	63	2
1870-71	..	..	9	..	19	5	20	2	5	..	7	..	60	7
1871-72	1	..	15	..	10	1	2	..	..	..	10	..	38	1
1872-73	1	..	..	..	3	..	8	..	18	..	16	..	46	..
1873-74	6	..	3	..	8	..	6	..	15	..	9	..	47	..
1874-75	..	..	10	..	22	3	3	1	21	..	14	..	70	4
1875-76	..	..	6	..	13	..	19	2	9	..	10	..	57	2
1876-77	..	..	5	..	4	..	7	..	3	..	12	..	31	..
1877-78	4	..	2	..	9	..	11	..	5	..	11	..	42	..
1878-79	1	..	6	..	21	3	26	1	12	..	11	..	77	4
1879-80	..	..	14	..	24	4	23	5	6	..	4	..	71	9
1880-81	3	..	10	..	6	..	19	10	11	..	11	..	60	10
1881-82	5	..	1	..	8	..	8	..	6	..	4	..	32	..
1882-83	1	..	4	..	10	..	4	..	3	..	22	..	44	..
1883-84	..	..	4	..	4	..	2	..	5	..	4	..	19	..
1884-85	..	..	7	..	3	..	20	..	4	..	13	..	47	..
1885-86	1	..	6	..	11	..	18	1	17	..	18	..	71	1
1886-87	..	..	5	..	17	3	19	3	17	1	18	..	76	7
1887-88	6	..	6	..	16	..	14	..	20	3	18	..	80	3
1888-89	7	..	..	..	11	..	12	1	18	2	12	1	60	4
1889-90	..	..	6	..	15	..	3	..	11	..	7	1	42	1
1890-91	2	..	6	1	25	6	20	3	14	..	9	..	76	10

TABLE V.
PROLONGED FROSTS OF THE LAST CENTURY, FROM OBSERVATIONS MADE IN LONDON AND ITS VICINITY.

Date.	Days duration.	Temperature.				Days.					
		Mean Max.	Mean Min.	Mean of Max. and Min.	Absolute Min.	Min. below 20°	Continuous frost.	Daily Mean 32° or below.	Max. 32° or below.	Max. 40° or above.	Absolute Max.
1788-9 Nov. 26 to Jan. 13 ¹ ..	49	31°·3	27°·5	29°·4	17°·5	4	12	33	30	3	46°
1794-5 Dec. 18 to Feb. 7 ..	52	31°·9	25°·3	28°·6	7	11	12	35	23	3	46
1813-4 Dec. 26 to Feb. 5 ..	42	33°·0	21°·5	27°·3	8	16	11	32	20	5	41
1838 Jan. 5 to Feb. 23 ..	50	32°·9	24°·9	28°·9	-4°·0	9	13	31	19	5	50
1855 Jan. 10 to Feb. 25 ..	47	34°·8	24°·5	29°·7	11°·1	12	4	31	15	7	48
1860-1 Dec. 15 to Jan. 19 ..	36	34°·9	24°·8	29°·9	8°·0	8	3	26	9	4	47
1879 Nov. 14 to Dec. 27 ..	44	37°·2	24°·7	31°·0	13°·7	4	2	22	6	12	55
1881 Jan. 7 to 26.....	20	31°·8	22°·1	27°·0	12°·7	10	9	14	12	1	41
1890-1 Nov. 25 to Jan. 22 ..	59	33°·5	25°·0	39°·3	12°·0	10	10	41	27	9	44

18th; it attained the thickness from 8½ to 5 ins. on March 10th, but skating was not allowed, the "Public being warned off the ice by notice" during the whole period of frost. In the Season 1886-7 skating was allowed on January 2nd and 8rd, the greatest thickness of the ice was 5 ins. In the Season 1887-8 there was no skating, but ice was frequently measured from December 28th to March 6th, the greatest thickness of the ice was, however, 2½ ins. In the Season 1888-9 ice was measured occasionally from January 7th to March 7th, but the thickness never exceeded ½ in., and it is needless to say no skating was permitted. In the season 1889-90 ice was measured frequently from December 2nd to March 6th, but there was no skating, and the greatest thickness of ice was 1½ in.

The return showing the state of the ice, &c. at Regent's Park contains the following, remark, the report being dated February 6th, 1891:—"It is too early to observe the full effects of the late frost on trees and shrubs; injury has been done, hollies and ivies are in many cases losing their leaves, privets and many other hardy shrubs are as if scorched by fire, hoar frosts have been dense, and must have affected the limbs of trees that are weakened by canker or other disease. Owing to the plentiful covering of snow during the sharpest weather, herbaceous vegetation has not suffered to any great extent.

"In contrast to the present winter, I may mention that last year the winter aconite was coming into flower on January 12th; by the 17th the primroses were blooming, and auriculas pushing up their trusses. At this season I do not observe a sign of movement from the winter aconite, and other plants, as the snowdrop and crocus, are still below the turf."

I have to thank the Meteorological Council for so kindly allowing me free use of information in the Meteorological Office, also the Council of the Royal Meteorological Society for the use of its valuable returns and the material assistance afforded in the compilation of the paper. I would also thank Mr. Symons for the large amount of material with which he has supplied me, and others who have so cordially assisted by the prompt supply of observations.

¹ The frost of 1788-9 has been included, as it occurred but little more than 100 years ago, the temperatures however are not from self-registering thermometers, but the observations used as the maximum were made at 2 p.m., and those for the minimum at 8 a.m. each day. The observations for all the other periods are from self-registering thermometers.

It may be interesting to mention that nearly all the prolonged frosts of the last century were followed by a fairly dry spring and summer, but the accompanying weather was by no means always hot.

DISCUSSION.

Dr. WILLIAMS said that this paper contained all the important facts relating to the great frost which had been recently experienced, and afforded abundant material for the formation of theories as to the cause of the prolonged cold weather. He had hoped that Mr. Harding would have explained more fully the cause of the comparatively warm weather which prevailed on the east coast of Scotland during this period. Travellers from the North of Scotland stated that no severe weather was experienced until they reached York, and the London district seems to have been visited with special severity. The effect of the prolonged cold on health was very unfavourable, especially in the case of the middle aged and elderly people, capillary bronchitis and pneumonia being induced, which often proved fatal in a few days.

Dr. BUCHAN said the high temperatures experienced at the sea-coast stations in Scotland were due to the fact that these places were situated on the western side of the extraordinary anticyclone which prevailed over the continent of Europe. In the Orkney and Shetland Islands the temperature during December was from $0^{\circ}5$ to $0^{\circ}8$ above the average, the wind in the Orkney Islands was from the South-east, and in the Shetland Islands the direction was South-south-west. In the north of Norway (which was situated on the northern side of the anticyclonic area) the temperature was from 5° to 7° above the average. To the southward the conditions which gave rise to low temperature prevailed, and they extended as far as Algeria. The intensity of the cold largely depended upon whether the polar winds, which were experienced, passed over a large extent of land or sea. The fact that no very intense cold was experienced over England during the period of the frost was due to the absence of bright sunshine, and, in consequence, to there being very little radiation. In Edinburgh only four or five hours of sunshine were recorded during December, and in London the amount was considerably less if any had been noted. The whole question of winter weather in the British Islands depended upon whether the cyclones occurring in Western Europe passed to the north or south of the British Islands. If we could forecast the course of winter cyclones, we could then forecast the character of our winter weather.

Mr. SCOTT remarked that no sunshine was registered by the recorder on the roof of the Meteorological Office during the month of December, and that only five minutes' sunshine was registered at Bunhill Row.

Mr. SYMONS called attention to the close resemblance which there was between Mr. Harding's chart of mean temperature over Ireland and that given by Prof. Hennessy in his paper on temperature.¹ He thought that a summary of Dr. Hellmann's recent paper on the depth of snow over Germany during the winter might be included in Mr. Harding's account of the frost. He also referred to the practical value of earth temperature observations in determining to what depth frost would penetrate the earth, more especially in connection with the question of what depth below the surface water mains and service pipes should be laid in order to be secure from the effects of frost. He also gave an account of the mischief wrought in the Camden Road through the Tramway Company using salt for thawing the snow on the tramway lines, and not removing the resultant slush, which, of course, was some 80° colder than the snow before the addition of the salt. He considered that one of the most remarkable temperatures recorded in the frost was the reading of $12^{\circ}2$ at Jersey.

Dr. MARCET stated that during the late frost the harbour at Geneva had been completely frozen over, and used as a promenade by the inhabitants of the city. He read the following extract from the *Journal de Genève*, of January 18th last, giving an interesting account of the past cold winters:—

"In 762 the cold was so great that the lake was completely frozen; this cold weather was followed by so great a heat that the plague broke out and several thousand people died.

"In 805 the cold was so intense that carriages crossed the lake on the ice from Thonon to Nyon.

"In 1196 the weather was so cold that all the trees and vines were killed; a hot season followed, and the heat was fatal to many people.

¹ *Proc. R. Irish Academy*. Vol. VI.

"In 1878 the cold was so great that all the trees and vines were dried up (séchés); a famine which lasted two years followed this cold period.

"In 1578 there was so cold a winter that several people were found dead in their own houses, the intensity of the cold put an end to the plague which prevailed at the time. In the month of March the River Arve rose so high from the melting of the snow that it arrested the current of the Rhone, so that the 'Rues-Basses and Plainpalais' (in the town) were under water.

"According to M. Forol, the distinguished Swiss Physicist, the Lake of Geneva was frozen in the years 1570, 1681, 1685, 1709, 1785 and 1788. Within the present century the harbour was frozen in 1810, 1820, 1880, 1854, 1890, and 1891."

Dr. TRIPE inquired how it was that at the present time, with an anticyclone as high as that which prevailed during the recent frost, dry and mild weather was being experienced. He thought that the falling-off in the death-rate of middle-aged and elderly people before the cold weather ended was due to the fact that the severe weather had already lasted a sufficiently long time to kill all such persons as were specially susceptible to cold.

Mr. HARRIES, referring to the suggestion of a probable connection between the long frost and the conditions which brought such an abnormal quantity of ice into the Atlantic last year, said that an examination of the European Daily Weather Reports showed the cold weather to have set in on the evening of November 16th over North-Eastern Russia. The morning temperature at Archangel was 36°, barometer 29.9 ins. By the evening the barometer had risen, from the eastward, to 30.3 ins., and next morning the temperature was -11°. Henceforward the weather under the influence of the Siberian anticyclone was very cold, but over Western Europe an anticyclone which had come from the Atlantic was accompanied by warm weather. From November 19th low pressure systems travelled between these anticyclones in a south-easterly direction from Iceland to Hungary, and on the 24th the high pressure and low temperature in the north of Europe were spreading in a south-westerly direction over Scandinavia. The East winds of this system covered the British Isles on the 25th, and next day nearly the whole of Europe was affected. The origin of our severe weather, therefore, was to be sought for in the far East—over Siberia—and not in the West. (The Atlantic ice had been set free in Northern Greenland as long ago as the summer of 1889). During the two months under discussion we were visited by several cyclonic and anticyclonic areas, but the former were not all mild, neither were the latter all cold. It follows from this that we must study our weather systems, not so much according to the high or low barometer, as to the special characteristics of individual areas, these depending upon the source or sources from which each derives its supply of air, the East wind of one anticyclone bringing with it a sharp frost, and that of another anticyclone a decided thaw.

Mr. SOUTHALL said that as Mr. Harding had referred to the thickness of ice, it might be of interest to state that in 1789-40 the ice in St. James's Park attained the thickness of 10½ inches. On the River Wye, in January 1795, the ice was a little over 1 foot thick, and during the recent frost it varied from 10 to 16 inches. In the neighbourhood of Ross the effect of the late frost on vegetation was not nearly so injurious as in 1838, 1861, or even 1881.

Mr. ROSTRON said that in the neighbourhood of Beddington more inconvenience was experienced from the freezing of water pipes after the thaw had commenced than before. On the second morning of the thaw he found the rain in the receiver of his rain gauge frozen into a solid piece of ice, a circumstance which had not taken place during the whole of his previous observations of 10 years. The injury to plants in his neighbourhood was most dreadful; even the hardiest evergreens had suffered severely, and he believed that it would be found when spring time came that the damage was even greater than at present it appeared to be. One feature of the frost was the great contrast between the temperature of the north of England and of Scotland and that of the south of England. He was at first led to suppose that this feature in long and severe frosts was unique; but from some records given by Dr. Derham in the *Gentleman's Magazine*, Vol. 84, Part 1, p. 142, he had found that in 1708-9 there was a similar contrast. Another prominent fact in connection with the recent frost was that the minimum on particular days occurred early in the evening. The

very low reading of $2^{\circ}6$ registered at Beddington on November 28th occurred at about 5 p.m. He was disposed to accept the Somerset House values quoted by Mr. Harding with some reserve. He had compared them with some apparently reliable observations made at 8 a.m., noon, and 11 p.m. by Cary, an optician, in the Strand, and published in the *Gentleman's Magazine*, and was inclined to think that the Somerset House temperatures were too low.

Dr. BUCHAN pointed out that in studying anticyclonic systems it was not sufficient to consider surface winds only, as upper currents played a very important part in their production. The anticyclone which at present was over the British Isles had come from the Atlantic.

Mr. C. HARDING, in reply, said that there was little doubt that we must have a much better knowledge of the movements of cyclones and anticyclones before we could hope to make any great advance in meteorology. During the anticyclone which prevailed in January last the barometer in Ireland attained probably the highest reading on record. This high pressure area came from Europe, and from a study of ships' logs he had found that when in about 80° west Longitude the barometer registered a pressure exceeding 81 ins. The temperatures recorded during an anticyclone depended upon where the supply of air was drawn from; and in the case of November 28th and 29th the air was drawn from Northern Europe. In the case of the present anticyclone the conditions were different, the high pressure area being situated immediately over England, and its area being considerably less than in the case of the January anticyclone. He believed the Somerset House values were quite reliable, as there was good evidence that the observations were carefully made.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

JANUARY 21st, 1891.

Ordinary Meeting.

W. H. DINES, B.A., Vice-President, in the Chair.

JOHN HERBERT WILSON, 6 West Park, Harrogate, was balloted for and duly elected a Fellow of the Society.

The following Papers were read :—

"NOTE ON A PECULIAR DEVELOPMENT OF CIRRUS CLOUD OBSERVED IN SOUTHERN SWITZERLAND." By ROBERT H. SCOTT, M.A., F.R.S. (p. 78.)

"SOME REMARKS ON DEW." By COL. W. F. BADGLEY, F.R.Met.Soc. (p. 80).

JANUARY 21st, 1891.

Annual General Meeting.

W. H. DINES, B.A., Vice-President, in the Chair.

Mr. F. B. EDMONDS and Mr. R. W. MUNRO were appointed Scrutineers of the Ballot for Officers and Council.

Dr. TRIPE read the Report of the Council and the Balance Sheet for the past year. (p. 47.)

It was proposed by the CHAIRMAN, seconded by Dr. TRIPE, and resolved :—
 "That the Report of the Council be received and adopted, and printed in the *Quarterly Journal*."

It was proposed by Dr. MARCET, seconded by the Hon. F. A. R. RUSSELL, and resolved :—"That the thanks of the Royal Meteorological Society be communicated to the President and Council of the Institution of Civil Engineers for having granted the Society free permission to hold its Meetings in the rooms of the Institution."

It was proposed by Mr. CHATTERTON, seconded by Mr. C. HARDING, and resolved :—"That the thanks of the Society be given to the President for his services during the past year."

It was proposed by Mr. M. JACKSON, seconded by Mr. MILLER, and resolved :—"That the thanks of the Society be given to the Officers and other Members of the Council for their services during the past year."

It was proposed by Mr. HARRIES, seconded by Mr. T. W. BAKER, and resolved :—"That the thanks of the Society be given to the Standing Committees, and to the Auditors ; and that the Committees be requested to continue their duties till the next Council Meeting."

The Scrutineers declared the following gentlemen to be the Officers and Council for the ensuing year, viz.:—

President.

BALDWIN LATHAM, M.Inst.C.E., F.G.S.

Vice-Presidents.

ARTHUR BREWIN.

CAPT. JOHN PEARSE MACLEAR, R.N., F.R.G.S.

WILLIAM MARCET, M.D., F.R.S., F.C.S.

CHARLES THEODORE WILLIAMS, M.A., M.D., F.R.C.P.

Treasurer.

HENRY PERIGAL, F.R.A.S., F.R.M.S.

Trustees.

HON. FRANCIS ALBERT ROLLO RUSSELL, M.A.

STEPHEN WILLIAM SILVER, F.R.G.S.

Secretaries.

GEORGE JAMES SYMONS, F.R.S.

JOHN WILLIAM TRIPE, M.D., M.R.C.P.Ed.

Foreign Secretary.

ROBERT HENRY SCOTT, M.A., F.R.S., F.G.S.

Council.

FRANCIS CAMPBELL BAYARD, LL.M.

HENRY FRANCIS BLANFORD, F.R.S., F.G.S.

GEORGE CHATTERTON, M.A., M.Inst.C.E.

ARTHUR WILLIAM CLAYDEN, M.A., F.G.S.

WILLIAM HENRY DINES, B.A.

WILLIAM ELLIS, F.R.A.S.

CHARLES HARDING.

RICHARD INWARDS, F.R.A.S.

HENRY JOHN MARTEN, M.Inst.C.E.

EDWARD MAWLEY, F.R.H.S.
HENRY SOUTHALL.
WILLIAM BLOMEFIELD TRIPP, M.Inst.C.E.

FEBRUARY 18th, 1891.

Ordinary Meeting.

C. T. WILLIAMS, M.A., M.D., Vice-President, in the Chair.

CHARLES LEWIS BROOK, B.A., Harewood Lodge, Meltham, Huddersfield ;
CHARLES EUGENE DE RANCE, F.G.S., F.R.G.S., Alderley Edge, Manchester ;
JOSEPH EDEN, Assoc.M.Inst.C.E., Glenae House, Workington ;
JAMES CHARLES MUNDELL, Moor Park, Rickmansworth ; and
JAMES SIDEBOTTOM, J.P., Millbrook, Hollingworth, near Manchester ;
were balloted for and duly elected Fellows of the Society.

The following Papers were read :—

"THE GREAT FROST OF 1890-1891." By CHARLES HARDING, F.R.Met.Soc.
(p. 93.)

"THE PROBLEM OF PROBABLE ERROR AS APPLIED TO METEOROLOGY." By
THOMAS WILLIAM BACKHOUSE. (p. 87.)

CORRESPONDENCE AND NOTES.

METEOROLOGICAL NOTES TAKEN ON THE SOUTH-EAST COAST OF MADAGASCAR,
August 1889 to July 1890. By the Rev. GEORGE A. SHAW.

FARAFANGANA, or Ambàhy, one of the few ports on the east coast south of Mānan-jāra, is situated in S. Lat. 22° 49 and E. Long. 47° 58'. It is enclosed on two sides by rivers of considerable volume which join to form a large lagoon between the town and the sea, and separated from the sea by a small bank of sand, which is constantly shifting, according to the relative strength of the two rivers and the force of the waves that break outside. Hence the opening to the sea is at one time in one place, at another time this is filled with sand, and the rivers break through at a spot which may be half a mile distant from the previous opening. At times each river forces a passage for itself in a line with the lower part of its course, leaving the bank of sand between as the eastern boundary of the lagoon. These openings, however, are always shallow, impeded with rocks and sand bars upon which the sea breaks with considerable violence. Close in-shore the southern half of the equatorial Indian Ocean current runs towards the south, at times with great rapidity. This extends to about 60 miles to the east, and naturally has its influence both on the climate and the wind, the latter blowing for days from the North or North-east, while at over 60 miles from shore only Southerly winds have been met.

On the west of the town are one or two swamps of sufficient extent to affect somewhat the climate of the place, and this factor, taken in conjunction with the large extent of forest immediately adjoining and extending towards the west, materially absorb, by the rapid evaporation during the night, the heat accumulated during the day. More especially so, as a land breeze blows with few exceptions every night throughout the year, springing up soon after sunset and continuing until 9 or 10 o'clock a.m. The exceptions depend entirely upon the strength of the wind during the day, especially if it is a Southerly wind, which often continues to blow throughout the night from the same point.

The observations from August 1889 to July 1890 have been taken in accordance with the instructions issued by the Royal Meteorological Society, with the exception of the barometer, an aneroid having been used instead of the usual standard barometer. The dry bulb, the wet bulb, and the maximum and minimum thermometers are in a Stevenson screen which is 4 ft. above the ground

covered with grass ; the black bulb thermometer *in vacuo* has the same elevation ; the minimum thermometer for terrestrial radiation is placed over short grass with the bulb just touching the tips of the blades.

Another variation from the Royal Meteorological Society's instructions is in the time of the second observation, which has been taken at 3 p.m. instead of 9 p.m., because both at 9 a.m. and 9 p.m. the land breeze is often blowing, and unless a third observation is added or the later time altered, the main characteristics of the day are missed.

The barometer has ranged from 29·94 ins. on March 3rd to 30·67 ins. on August 21st, 1889. The barometer stood highest during the previous August of any month in that year.

The greatest heat in the shade in a clear current of wind was 94° on January 7th. Three times in the same month 93° was registered, and ten times during the year the mercury stood at 92°. The greatest heat of the direct rays of the sun, as tested by the black bulb thermometer *in vacuo*, was registered on January 7th, when the mercury stood at 164°.

The lowest minimum of the air 4 ft. from the ground was noted on November 7th, when after a drizzling afternoon the thermometer during the night fell to 50°.

The lowest record of intensity of terrestrial radiation was on July 30th, when 40° was registered.

Rain fell on 181 days during the year ; the greatest amount in any single day of 24 hours fell on January 30th, when 6·73 ins. was measured.

The total rainfall for each month has been as under :—

		Ins.			Ins.
1889	August	13·70	1890	February	25·14
"	September	3·60	"	March	24·60
"	October	4·59	"	April	6·31
"	November	1·50	"	May	9·60
"	December	11·96	"	June	13·37
1890	January	24·00	"	July	6·97

making a total of 145·34 ins. for the year.

The wind, at time of observation, viz. either 9 a.m. or 3 p.m. or both, was blowing :—

Between North and East including North on 158 days.

"	East	"	South	"	East	"	134
"	South	"	West	"	South	"	40
"	West	"	North	"	West	"	62

The great majority of the Westerly winds were registered at the 9 a.m. observation and represented the land breeze.

The following are the averages for each month :—

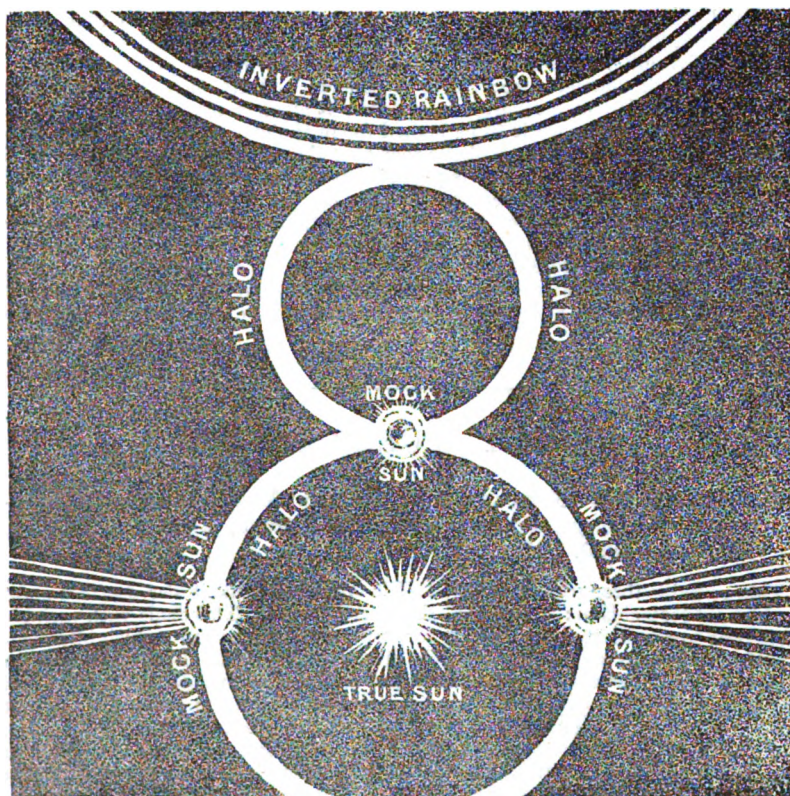
Month.	At 9 a.m.					At 3 p.m.							
	Barometer.	Thermo- meter.		Force of Wind. 0-12.	Amount of Cloud. 0-10.	Barometer.	Thermo- meter.		Force of Wind. 0-12.	Amount of Cloud. 0-10.	Max. in Shade.	Min. in Shade.	Max. in Sun, Black Bulb <i>in vacuo</i> .
		Dry Bulb.	Wet Bulb.				Dry Bulb.	Wet Bulb.					
1889.	Ins.	°				Ins.	°						
August ..	30°51	72	62	2	3	30°48	76	72	3	4	83	58	128
September	30°41	74	70·9	2	3	30°38	79·4	72	3·4	3·8	83	57	132
October ..	30°39	77·8	73·9	2	4	30°36	80·7	74·4	3	3	83·8	61·2	136
November	30°29	83·4	78·6	2·6	3·4	30°25	85·3	80·2	3·7	3	87·3	64·6	143·5
December	30°23	84·7	79·7	2·7	4·6	30°17	86·3	80·8	3·7	5·9	89·2	67·3	144·5
1890.													
January	30°25	83	78	2·4	4	30°21	84·8	79	3·9	4·5	88·4	70·6	148·9
February	30°23	82·8	78	2	7	30°19	84	79	3	4	87	71	144
March ..	30°34	82	78	2	3	30°21	84	80	3	4	87·4	73	144
April	30°31	83	78	2	4	30°29	84	79	3	4	86	67	139
May	30°36	77·7	72·3	3	4	30°34	79	73	4	4	84	60	131
June	30°44	72·3	63	2·8	3·8	30°41	78·4	71·9	3	4·7	80·6	57	127
July	30°45	74·3	69·6	3	4	30°43	77·8	72·7	3	4	80·4	57·7	130

HALOS AND PARHELIA AT CAROWA, NEW SOUTH WALES, October 10th, 1890. By H. C. RUSSELL, B.A., F.R.S., Government Astronomer.

ON the afternoon of October 10th, 1890, Mr. James Crawford Leslie, Editor of the *Carowa Free Press*, and his three sons observed parhelia about the sun. The weather threatened rain, and a change was coming on. An immense halo appeared round the sun, a portion of it being below the horizon, as shown in the sketch; on either side of this at the same altitude as the sun was a mock sun. Soon after this a brilliant and well-defined but inverted rainbow became apparent in the zenith, and closer observation revealed a ring of light joining the halo and the rainbow. Where this ring of light crossed the halo was a third mock sun. The sun's rays appeared to project through the two horizontal mock suns. The whole display lasted about 30 minutes, and was witnessed by a number of persons in addition to those named.

At my request Mr. Leslie made full inquiry to ascertain if any one had seen rings of light cutting the halo at the points where the mock suns were, but no one saw them. Mr. Leslie's sons had observed carefully, and two prepared drawings from which the engraving was made. The halo and parhelia were also observed at Albury, about 30 miles east of Carowa. Carowa is on the north side of the Murray River, about 30 miles west of Albury.

ZENITH



HORIZON

THE SEA-BREEZE.

THE New England Meteorological Society in 1887 undertook an investigation of the Sea-Breeze, and have now published a Report¹ on the same which has been prepared by Prof. W. M. Davis, Sergeant L. G. Schultz, and Mr. R. De C. Ward. The Report concludes as follows:—

"The sea-breeze must be reckoned as one of the minor climatic features of New England. In the summer of 1887 it took possession of a narrow strip of the Eastern Coast of Massachusetts on 30 days, and judging by the weather of that season, this number may fall somewhat below the normal for the same period in other years. The occurrence of the breeze depends on the general weather of the region; it appears most distinctly on warm, clear, quiet days, and is absent on cool, cloudy, and rainy days, and on days with strong winds of any direction. It comes in to the shore from the sea, working its way against a belt of calm air, as is the case with the tropical sea breeze; and it exhibits the veering with the sun as the day passes that is noticed in winds of its kind elsewhere. It reaches the shore commonly between eight and eleven o'clock in the forenoon with a velocity of 10 or 15 miles an hour, its velocity rapidly diminishes inland. Its inland advance from the shore-line is made at first at a rate of from three to eight miles an hour, but slower afterwards when approaching its greatest penetration of 10 or 20 miles in the late afternoon. It produces a distinct and agreeable depression of temperature on the coast, but this effect is not carried inland as far as its wind extends; neither is the effect as great as that produced by the "sea-turn," or Easterly cyclonic wind of our coast. The district of most persistent occurrence and greatest penetration of our sea-breeze is from Boston to Cape Ann, along what is known as the "North Shore," where the north-east trend of the coast-line favours its development in combination with the prevalent South-westerly wind of summer time; South of Boston and North of Cape Ann, the South-westerly wind often reverses it or drives it away in the afternoon.

"The origin of the breeze is to be looked for in the diurnal excess of the temperature of the air over the land above that over the sea, in the manner best stated by Captain Seemann. The breeze is part of a littoral convectional circulation, but in the morning, while the temperature over the land is rising rapidly and the convectional circulation is in process of establishment, the outward expansion of the land-air holds the in-coming breeze off-shore for a time, thus causing its first appearance to be not close on the coast-line, but in the offing like 'a fine, small, black curve upon the water, when all the sea between it and the shore not yet reached by it is smooth and even as glass in comparison,' as Dampier long ago observed."

RECENT PUBLICATIONS.

ABHANDLUNGEN DES KÖNIGLICH PREUSSISCHEN METEOROLOGISCHEN INSTITUTES. Herausgegeben durch W. von Bezold, Direktor. Band I., Nos. 1-8. 1890. 4to.

This contains three papers, viz. :—1. Die Veränderlichkeit der Lufttemperatur in Norddeutschland: von Dr. V. Kremser (32 pp.). This deals with variable periods of years, so that the results for different stations are not rigidly comparable with each other.—2. Bericht über vergleichende Beobachtungen an verschiedenen Thermometer-Aufstellungen zu Gr. Lichterfelde bei Berlin: von Dr. A. Sprung (27 pp.). This gives an account of the comparison of a great number of different thermometer exposures, which were read six times a day. The principal results are that all the window exposures were in excess, but in screens like Wild's or with thermometers quite open, if perfectly sheltered from the sun, they give very accordant results. Of the free standing screens Stevenson's, at least that of the Royal Meteorological Society, comes out decidedly the

¹ *Annals of the Astronomical Observatory at Harvard College*. Vol. XXI. Part II. 1890.

best. Dr. Sprung, however, points out that the perfectly open exposure of a thermometer screen is even harder to obtain than that of a rain-gauge, and he also points out that if the thermometers are far from a house readings may be carelessly taken. As a final conclusion the Prussian Institute recommends that window screens should be used in general, and that if no suitable window is available the Stevenson screen should be employed.—3. Bericht über vergleichende Beobachtungen an Regenmessern verschiedener Konstruktion : von Dr. G. Hellmann (13 pp.). The rain gauges tested were all German, as one most important particular to be ascertained was the fitness of the gauges for catching snow. As regards the measurement two collecting funnels and cylinders are supplied with each gauge, and if snow has fallen the empty cylinder is to be placed on the gauge and the full one taken into the house to thaw. The gauge recommended is Hellmann's, a 6-inch cylinder, with brass conical rim sharply cut at top. The rims are all stamped on testing, and any showing an error of ± 0.3 mm. are rejected.

AMERICAN METEOROLOGICAL JOURNAL. A Monthly Review of Meteorology and Medical Climatology. January-March 1891. Vol. VII. Nos. 9-11. 8vo.

The principal original articles are :—The New England Meteorological Society (10 pp.). This is an account of the proceedings at the Meeting of this Society on October 21st, 1890, when the special topic of Tornadoes was discussed.—The Meteorological Observatory recently established on Mont Blanc : by A. L. Rotch (4 pp.). A cabin has been built on Mont Blanc at an altitude of about 14,320 ft. above sea-level, at which a set of recording instruments, by MM. Richard Frères, has been installed, thus rendering this the highest meteorological station in the world.—The Gervais Lake Tornado : Is a modern fire-proof building tornado-proof? by P. F. Lyons (6 pp.).—Photograph of the Lake Gervais Tornado Funnel : by the Editors (7 pp.). A reproduction of this photograph is given, the Editors having assured themselves both of its authenticity and also that the plate had not been "touched-up."—Observations and Studies on Mount Washington : by Prof. H. A. Hazen (12 pp.).—Accessory Phenomena of Cyclones : by H. Faye (7 pp.).—The State Weather Service : by Prof. F. E. Nipher (6 pp.). This was an address delivered by request of the State Board of Agriculture at Jefferson City, Mo., January 15th, 1891.—Wind Pressures and the measurement of Wind Velocities : by Prof. C. F. Marvin (10 pp.).—Meteorological Observations taken in four Balloon Voyages : by W. H. Hammon (31 pp.). These ascents were made under the direction of the Signal Office in January, March, and April 1885. The observations are given *in extenso*.—Prof. Russell's Theory of Cold Waves : by S. M. Ballou (14 pp.).—Temperature in High and Low Areas (8 pp.).—State Tornado Charts : by Lieut. J. P. Finley (6 pp.). The State here dealt with is New York.

DAS KÖNIGLICH PREUSSISCHE METEOROLOGISCHE INSTITUT IN BERLIN UND DESSEN OBSERVATORIUM BEI POTSDAM. Aus amtlichem Anlass herausgegeben von W. von Bezold, Director. 1890. 4to. 76 pp. and 4 plates.

This is an account of the organisation of the Prussian Meteorological Office ; it is uniform in size with a similar account of the Astronomophysical Institution. The pamphlet gives a history of the gradual development of meteorological organisations in Germany, from the date of the Societas Meteorologica Palatina in 1780.

JOURNAL OF THE SCOTTISH METEOROLOGICAL SOCIETY. Vol. IX. Third Series. No. VII. 8vo. 1891.

This part contains a number of papers discussing various observations made at the Ben Nevis Observatory, among which are the following : (1.) Meteorology of Ben Nevis ; by Dr. Buchan (11 pp.).—(2.) Daily mean temperatures at Ben Nevis Observatory and Fort William : by R. T. Omond (5 pp.).—(3.) Reduction of estimated wind forces to velocity in miles per hour at Ben Nevis Observatory ; by R. T. Omond (1 p.).—and (4.) Thunderstorms at Ben Nevis Observatory : by R. C. Mossman (6 pp.). The other papers are : Influenza and Weather of London : by Sir A. Mitchell and Dr. Buchan (12 pp.) ; and Hygrometry in the *Meteorological Journal* : by C. Piazzi Smyth (2 pp.).

METEOROLOGISCHE ZEITSCHRIFT. Herausgegeben von Dr. J. HANN und Dr. W. KÖPPEN. December 1890-March 1891. 4to.

The principal articles are:—*Untersuchungen über die Ursachen der unperiodischen Luftdruckschwankungen*: von F. Klitzkowski (14 pp.). This is an attempt to give a mathematical explanation of the causes of storms on the basis of Dr. Werner von Siemens' papers, which have been noticed in this *Journal* for January (p. 44).—*Bühler's Hagelstatistik und vorläufige Mittheilung einer säkularen Periode der Hagel- und Blitz-Gefahr*: von C. Lang (9 pp.). The report reviewed refers to the hail records of Württemberg for 60 years, 1828-87. It deals solely with damage done by hail as recorded in the Government Insurance Offices, and so does not go *pari passu* with thunderstorm inquiries; and it also treats only of the months at which crops are growing, &c. Speaking generally, Bühler recognises that maxima of hail damage coincide with minima of sun spot frequency; but although he has a period of 60 years, his figures do not give a very regular curve. It appears, moreover, that the frequency of hail is not increasing, but the contrary. As regards the alleged protection given by woods against damage, Dr. Bühler is unable to find any confirmation of the belief, and says that the question is inextricably mixed up with that of the influence of hill and valley.—*Ein Apparat zur Ventilation des feuchten Thermometers*: von Dr. R. Assmann (9 pp.). This is a description of the mode of ventilating the wet bulb by means of an aspirator, and Dr. Assmann contends that his plan insures a definite reading of the wet bulb, even in frost, in five minutes; whereas, when the bulb is left to itself, it often takes half-an-hour before the reading becomes steady.—*Ueber den Einfluss des Waldes auf die periodischen Veränderungen der Lufttemperatur*: von Dr. A. Müttrich (21 pp.). The author discusses the same subject as was treated of lately by Herr Eckert for Austria, but deals with fuller material. He has 15 years' observations nearly complete for 16 stations in North Germany. The results are worked out in great detail, but the minutiae are hardly of general interest.—*Ueber die ältesten meteorologischen Beobachtungen von Wien*: von J. Leznar (10 pp.). This is a discussion of the observations of Pilgram in Vienna from 1762 to 1786. Dove quoted his figures as daily temperatures; but for most of the time they were early morning observations, probably taken at 6 a.m., and consequently too low. His thermometers were self-made, and probably not quite correctly marked at the fixed points. Pilgram must have been a bit of a wag. The Mannheim Academy proposed a scale of 1-4 for the wind. He said: "For the country and small towns the scale is good enough, but how shall we notice the motion of foliage in a city? We must only understand that we are to observe the foliage of the gardens the ladies wear on their hats, and the scale would be:

1. A wind which moves the wreaths.
2. Blows away the wreaths.
3. Blows away the hats.
4. Blows away the ladies, hats, and all."

—*Zur Beurtheilung der Evaporationskraft eines Klimas*: von Dr. M. Ule (5 pp.). This is an attempt to set at rest the question whether we should give relative humidity, or difference between that and saturation, or any other of the various modes of attacking evaporation. Dr. Ule suggests the following formula:—

$$\text{Evaporation} = A\Sigma(t-t')w.$$

Σ Implies that $(t-t')$ is to be calculated for each observation during the time for which the evaporation is to be determined and w is the wind. Dr. Ule admits that his formula would show no evaporation if a calm occurred, but otherwise his figures are fairly consistent *inter se*.

SAILOR'S HAND BOOK OF STORM TRACK AND ICE CHARTS. By LIEUT. JOHN P. FINLEY, Signal Corps U.S. Army, &c.

Lieutenant Finley says in his Preface that "the subject under discussion in this volume relates directly to the distribution and frequency of atmospheric disturbances, and the attendant movements of fog and ice over certain portions of the North Atlantic Ocean."

The construction of the charts is next explained. Then come explanatory tables, and finally the charts themselves, which we shall take in the order in which they appear.

1. Storm Track Charts. Of these there are 12, one for each month, representing the tracks of storm centres for the period of 10 years, 1875-84. These tracks are represented by a mass of confused lines covering the northern portion of the Ocean, and so interlaced one with another that individual tracks can scarcely be followed. Lieut. Finley states:—"By a storm centre is meant the centre of a region in which gales of the force of 4 to 6 on Beaufort Scale are experienced." There must be some misconception here, as the lowest figure for a gale on Beaufort's Scale is 7. Perhaps Mr. Finley refers to the Land Scale (0-6), but that is not Beaufort's.

2. Hurricane Chart. This possesses the same defect as the preceding series. The lines interlace and are almost undecipherable. The chart also is very badly lithographed, which renders it less legible.

3. Hurricane Chart of the Gulf of Mexico. This is much clearer. It would be improved if drawn on a larger scale.

4. Storm Frequency Charts. Of these there are 12 monthly and one annual chart, 13 in all. They are much clearer than the Storm Track Charts, and are interesting.

5. Fog Charts. These are monthly, and they show by curves the "average," "probable," and "extreme" limits of their occurrence, mainly about the banks of Newfoundland. As to this classification, the "average" and "extreme" data are taken from the U. S. Hydrographic Office data, the "probable" data from Signal Service publications. The result of this combination of incongruous data is that in several months the "probable" area, so far from coinciding with the "average," is far beyond the "extreme" area, notably so from August to November! The fog region never reaches the British Isles!

6. Ice Charts. These resemble the fog charts, and are affected by the same confusion of ideas as to the "average," "probable," and "extreme" limits.

SYMONS'S MONTHLY METEOROLOGICAL MAGAZINE. January-March 1891. Nos. 800-802. 8vo.

The principal contents are: The Frost of 1890-91 (6 pp.).—Hail Insurance (2 pp.).—Frost Penetration (2 pp.).—Grass Thermometers in time of Snow: by J. Baxendell (1 p.).—February 1891 (8 pp.). This gives details of the distribution of rainfall over the British Isles during the month, which was abnormally small. At many stations no rain whatever was recorded during the month.—Merle's MS. Observations A.D. 1337-1344 (1 p.).

TRANSACTIONS OF THE HERTFORDSHIRE NATURAL HISTORY SOCIETY AND FIELD CLUB. Vol. VI. Parts 1-8. 1890. 8vo.

Contains among other articles: A record of water-level in a deep chalk well at Odsey Grange, Royston, 1878-1888; by H. G. Fordham (6 pp. and 2 plates). The author gives the measurements of the water-level in this well on March 1st in each year, and also the annual rainfall. Comparing the results with measurements made in two other wells he finds that the movements of the water are slightly later in time in the deeper wells, on the higher ground at Therfield and Barley than at Odsey, while at the same time a close parallelism is maintained in the curves representing the changes of level in the three wells. The rise from November to March, and the subsequent fall, take place with more or less modification from the mean curve year by year; any abnormal development in the annual curve being generally associated with some exceptional condition relative to the autumn and winter rainfall, and but rarely to that of the spring or autumn. —Half a Century's Rainfall in Hertfordshire: by J. Hopkinson (10 pp. and map). There was 1 station at work during the decade 1840-49; 2 in 1850-59; 7 in 1860-69; 12 in 1870-79; and 18 in 1880-89; while in 1889 there were 30 gauges at work in the county. The mean rainfall during each decade was as follows:—

1840-49	1850-59	1860-69	1870-79	1880-89
25·82	25·50	26·11	27·97	26·74

The mean for the 50 years 1840-89 was 26·43 ins.

TRANSACTIONS OF THE ROYAL SOCIETY OF EDINBURGH. Vol. XXXIV. 4to. 1890. 406 pp.

This is devoted entirely to an account of the Meteorology of Ben Nevis. It contains the detailed hourly observations made at the Ben Nevis Observatory, and the five daily observations at Fort William, from December 1st, 1883, to December 31st, 1887, and is prefaced by a Report by Dr. Buchan on the Meteorology of Ben Nevis, based on these observations. The Observatory Log Book is also given *in extenso*, which contains much valuable and interesting information, not only of a scientific nature, but also on the difficulties encountered by the assistants in carrying on the observations.

WEATHER FORECASTING FOR THE BRITISH ISLANDS by means of a Barometer, the Direction and Force of the Wind, and Cirrus Clouds. By CAPT. HENRY TOYNBEE, F.R.A.S. 8vo. 1890. 86 pp.

In 1888 and 1889 Capt. Toynbee, at the request of the Council of the Meteorological Office, lectured on the use of the barometer to seafaring men at various ports in the North of Ireland and North-west of England. A desire was expressed that the lecture should be published: hence the present little manual. The object of the lecture is to show what a single observer can do towards forecasting wind and weather at his station, supposing him to have a barometer, means for observing roughly the direction and force of the wind, and power to recognise cirrus clouds and the direction from which they are coming. The work is illustrated with a number of plates and diagrams.

ZEITSCHRIFT FÜR INSTRUMENTENKUNDE. Neunter Jahrgang. March 1889. 4to.

Contains: Neue Registrirapparate für Regenfall und Wind, mit elektrischer Uebertragung: von Dr. A. Sprung und R. Fuess (8 pp.). This is a description of new electrical apparatus for recording rain and wind. As regards the former the authors use a lamp inside, as Babinet did in winter to melt snow. In the anemometer they use Robinson's cups, and a vane for direction. No account is given of the extent to which the battery is run out by the frequent changes of direction in a storm.

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Quarterly Journal

OF THE

ROYAL

METEOROLOGICAL

SOCIETY.

EDITED BY A
COMMITTEE OF THE COUNCIL.

JULY 1891.
VOL. XVII. No. 79.

LONDON:
EDWARD STANFORD, 26 & 27 COCKSPUR ST., CHARING CROSS, S.W.;
WILLIAMS AND STRAHAN, 7 LAWRENCE LANE, CHEAPSIDE, E.C.

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Royal Meteorological Society.

ESTABLISHED 1850. INCORPORATED BY ROYAL CHARTER, 1866.

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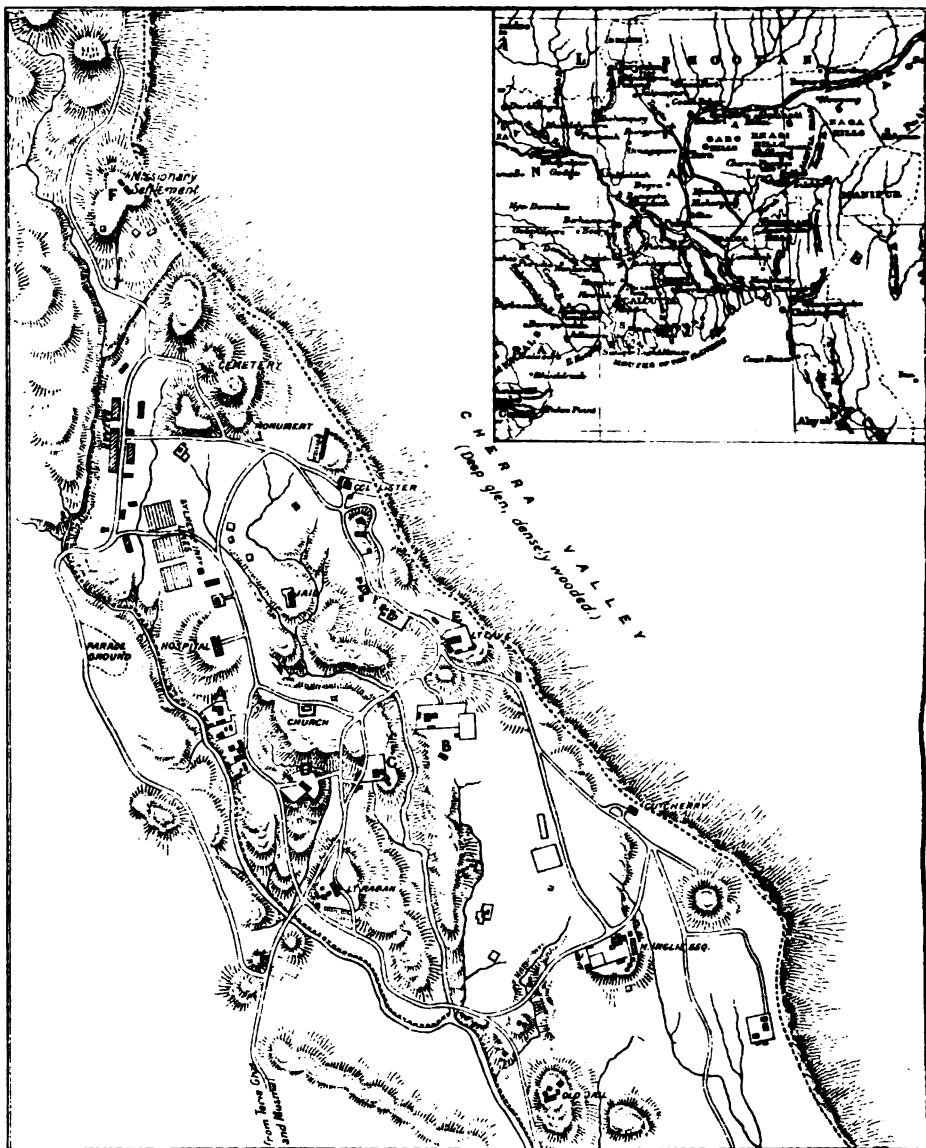
DEATH.

TAYLOR.—Sept. 14th, 1891, at Torquay, Herbert Coupland Taylor, M.D., J.P., of Todmorden Hall, Lancashire, and Quinta Rochedo, Madeira, son of the late James Taylor, of Todmorden Hall, Lancashire, and Culverlands, Berks, J.P. Aged 36.

Requiescat in pace.

MAP OF THE STATION OF CHERRA POONJEE, KHASI HILLS, IN 1853.
SHOWING THE POSITION OF THE RAIN GAUGES.

ALSO KEY MAP SHEWING SITUATION AS REGARDS CALCUTTA AND THE BAY OF BENGAL.



A.S. Connel & Co., Lith.

Scale 3 Inches = 1 Mile

Quart Journ. Roy. Met. Soc. Vol. XVII. Pl. 6



QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY.

VOL. XVII.

JULY 1891.

No. 79.

A CONTRIBUTION TO THE HISTORY OF RAIN GAUGES.¹

By G. J. SYMONS, F.R.S., Secretary.

[Read March 18th, 1891.]

OWING to the absence of our President in Oriental countries, it was felt by the Council that he could not be asked to prepare the Address relative to the Annual Exhibition, and I was requested to do so.

This paper is therefore one of the series in which Hygrometers, Anemometers, Instruments for Travellers, Thermometers, Sunshine Recorders, Barometers, Marine Instruments, Apparatus for studying Atmospheric Electricity, Solar Radiation Instruments, and the application of Photography to Meteorology, have been successively dealt with. I regret that I cannot, in the time at my disposal, make this as nearly complete as some of its predecessors were. My difficulties have also been aggravated by the fact that I cannot ascertain that any one has ever attempted to deal with the subject—even Poggendorff, in his excellent *Geschichte der Physik*, devotes less than half-a-page to it, and has not carried the history back so far as I have been able to do.

We are indebted to Dr. Hellmann for directing attention to what is probably the earliest measurement of rain, but, as will be seen, it was merely an

¹ By one of those curious coincidences which frequently occur, Dr. Hellmann was at work upon this subject at the same time as I was, and he has most kindly allowed me to use his data in the verification and completion of this Paper.—G. J. S.

isolated experiment, there is no suggestion of a rain gauge, or of a continuous record.

In an extremely interesting article¹ in a German periodical, Dr. Hellmann calls attention to a letter dated June 10, 1689, and addressed by B. Castelli to Galileo, in which he relates that after going to see a lake which was exceptionally low, he, on his return to Perugia, passed for eight hours through an apparently exceptionally heavy rain. This suggested to him the problem how much such a rain might raise the lake, and so, on reaching home, he put out a glass cylinder about 5 inches in diameter and 9 inches deep, and at the end of an hour took it in, and measured the depth of water in it. He does not give it in figures, but in the letter draws a line about 0.4 inch long to represent the depth.

Further evidence that this was an isolated case, and that the idea of regularly recording the fall of rain did not occur to Castelli, seems to be afforded by the fact that all through the Cimento MSS., which range from 1654 to 1664, and in the record very carefully kept at the Monastery of the Angels at Florence from 1654 to 1670, there is no reference to a rain gauge, though frequent statements are made as to the fall of rain and of snow. Had such an instrument as a rain gauge been known, I feel sure that one would at once have been added to the instruments at the monastery.

Most curiously, the first rain gauge designed was not an ordinary one, but a recording one. In Birch's *History of the Royal Society* we read that on January 22, 166½, Dr. Wren (*i.e.* Sir Christopher Wren) showed his experiment of filling a vessel with water, which emptied itself when filled to a certain height. Later on, September 28, 1668, Dr. Wilkins was desired to write to Dr. Wren for his scheme of the instrument for recording all sorts of weather. On November 30, 1668, Dr. Wilkins acquainted the Society that he had received an answer from Dr. Christopher Wren concerning his promised weather-clock, together with the scheme thereof. The amanuensis was ordered to draw the scheme in great (*i.e.* to prepare a diagram) against the next meeting, at which it should be considered, together with the letter describing it. On December 9, 1668, Dr. Wren's description of his weather-clock, consisting of two wings that may be added to a pendulum clock, was read and ordered to be registered. I do not reproduce this drawing because for some reason Sir Christopher did not propose to record anything except wind—and we are dealing with rain gauges, not with anemometers. But the other Fellows wished it completed, and, after some debate, the matter was referred to the Council to consider of the expenses, and of the most convenient way of reducing the engine into practice, as also of additions to be made thereto, whereof some were mentioned by Mr. Hooke, one of the officers of the Society. The Council was evidently alarmed at these additions, for five days later (December 14, 1668) it was ordered that Dr. Wren be desired to make an estimate of the charges of a plain weather-clock, such as he himself had devised; and to consider of the easiest contrivance to put it in practice.

¹ *Die Anfänge der Meteorologischen Beobachtungen und Instrumente.* Himmel und Erde II. Jahrg. 3 u. 4 Heft.

In 1664 (August) Hooke was provided with a residence in Gresham College (then the headquarters of the Royal Society), and directly afterwards, September 14, 1664, it was ordered that Mr. Hooke contrive a pendulum clock applicable to the observing changes of the weather, as well and as cheap as he could, for the use of the Society. In the following January Hooke showed the way whereby a thermometer might be made to indicate in connection with the weather-clock.

Then for several years nothing was done, but finally, on May 19, 1670, it was ordered that a weather-clock should be bespoken by Mr. Hooke; such a one as Dr. Wren had formerly contrived, for observing [recording] not only the winds and their quarters and degrees of strength, but also the quantities of rain, and other particulars relating to the temperature of the air.

It was thus nearly ten years between the date of Sir Christopher's suggesting his tipping-bucket rain gauge, and one being ordered for construction for the Royal Society. My impression is, however, that Sir Christopher, after showing his rain gauge to the Royal Society on January 22nd, 1662, took it home again, and recorded it regularly, although no trace of his observations can now be found. My reasons for this opinion are two: first that such a course was probable; secondly, that to a review of Perrault's *Origine des Fontaines* in the *Phil. Trans.* Nov. 22, 1675, there is the following note:—

“The like to which hath been attempted here, and proposed to the R. Soc. some years since, by Sir C. Wren, who by the contrivance of a rain bucket had taken an account of all the water that fell for a considerable time, and by his weather-clock had, among other particulars, not only taken in the measurement of the quantity of rain that falls, but also when it falls, and how much at each time.”

It had long been supposed that the observations made by Mr. Townley, of Townley, near Burnley, Lancashire, which began on January 1st, 1677, were the earliest in the world, but Poggendorff has shown that an unknown correspondent residing at Dijon had supplied Mariotte with records from that city dating back to about 1674, or three years before the Townley ones.

On carefully reading Mariotte's works, I found a reference to a rather scarce anonymous book, entitled *De l'origine des Fontaines*, printed in Paris in 1674. It is, of course, in old French, but of such interest that I think a few lines from p. 200 should be reprinted *verbatim*.

“Par les observations que j'ay faites de la quantité des eaux de pluye & de neige, j'ay trouvé que depuis le mois d'Octobre 1668, jufques à pareil mois de 1669, il en est tombé la hauteur de dix-huit poulces sept lignes: Depuis pareil mois de l'année 1670, jufques à pareil mois de 1671, il n'en est tombé que la hauteur d'onze poulces fix lignes feulement; & depuis le mois de Janvier 1673, jufques à pareil mois de 1674, la hauteur de vingt sept poulces fix lignes: Je joins ces trois quantitez ensemble pour en faire celle d'une année commune, qui fera par ce moyen de dix-neuf poulces deux lignes vn tiers.”

I had, from internal evidence, arrived at the conclusion that these observations were made in Paris, but thanks to the help of Mr. White, the Assistant Librarian of the Royal Society, the veil of anonymity is removed, and the observations prove to have been made in Paris by M. Pierre Perrault, in whose collected works the above anonymous book is reprinted with his signature.

Perhaps a brief digression respecting what led Perrault and Mariotte to make, and to have made, these observations, may be excused. Science made rapid advances during the years following the discovery of the barometer in 1648 : in 1648 there was Pascal's experiment on the variation of the barometer with altitude above sea-level, and in 1670 Mariotte proposed the synchronous study of winds over a large area, with a view to weather forecasting. Although the Biblical texts were perfectly clear as to the course of the vapour and the rivers (Job xxvi. 8 ; Isaiah lv. 10 ; Jer. x. 18 ; Eccl. i. 7) ; and Vitruvius, in his *Architectura*, had distinctly stated that springs were fed by stored-up rainfall, the matter had been so buried under false theories that the general opinion had swerved quite away from the truth, when Perrault took it up, and in the little book I have quoted, gave, first a thorough analysis of the many false explanations, and then the true explanation. For this he, of course, needed the returns of rainfall, and it is curious that his mean value for Paris 19''2½'' corresponds to 20·45 English inches, or within half-an-inch of the value for that city assigned by Prof. Raulin as the result of modern observation. M. Perrault dealt with the matter with great skill, considering the epoch. He had the rainfall, he allowed for evaporation, he made an estimate of the area of the watershed of the Seine and the Marne, and compared the probable discharge, with that of the combined rivers when passing through Paris.

Having started this question of priority I proceed to deal with, and dispose of it. I have placed Sir Christopher first on the list, because I believe that he was first, but I have attached a ? to the entry because I have not actual proof.

Doubtless the tables which I have prepared have faults. They are virtually challenges to the meteorologists of all countries, to prove, if they can, that they are entitled to higher positions than I have awarded to them ; and although I have taken pains to do justice to all, I include the tables in the paper that they may be corrected if, and where, they need it.

The first table gives a list of all rain-records commenced before 1700, viz.:

Country.	City or Place.	Observer.	Date.
? England,	London,	Sir Christopher Wren.	1662 ?
France,	Paris,	P. Perrault.	1668.
„	Dijon,		1674 ?
England,	Townley, Lancashire,	R. Townley.	1677.
France,	Paris,	Sédileau.	1688.
„	Lille,	Vauban.	1689.
England,	Gresham College, London,	R. Hooke.	1695.
„	Upminster, Essex,	Rev. W. Derham.	1697.

In the next table I have had to deal not merely with meteorology, but with politics. The map of Europe, and of the World, is not the same now as it was 224 years ago, and this has caused some difficulty in forming a list of the countries of the world, in the order of date of first systematic record of rainfall—which is what I have tried to compile. I do not think that the first five entries will be easily wrested from France, England, Italy, Switzerland, and Ireland respectively, but that very probably the entries of the later dates, *e.g.* for the nineteenth century, will require both modifications and additions.

Quarters.	Countries.	Towns.	Dates.
Europe	France	Paris	1668
"	England	Townley	1677
"	Italy	Pisa	1707
"	Switzerland	Zürich	1708
"	Ireland	Londonderry	1711
"	Wurtemberg	Ulm	1712
"	Holland	Leyden	1717
"	Prussia	Breslau	1717
"	Scotland	Edinburgh	1781
"	Russia	St. Petersburg	1788
North America	South Carolina	Charleston	1788
Europe	Sweden	Upsala	1789
Africa	Madeira	Funchal	1747
West Indies	Antigua	—	1751
"	Martinique	St. Pierre	1751.
"	St. Domingo	Haïti	1761
Europe	Austria	Kremsmünster	1768
"	Norway	Bergen	1765
"	Denmark	Copenhagen	1769
Asia	Madras	Madras	1777
Europe	Belgium	Brussels	1779
"	Spain	Barcelona	1780
West Indies	Guadaloupe	La Point à Pitre	1782
Europe	Portugal	Lisbon	1788
Asia	Bengal	Calcutta	1784
Africa	Mauritius	Port Louis	1786
South America	French Guiana	Cayenne	1788
West Indies	Cuba	Havanah	1811
Asia	China	Canton	1812
Europe	Bavaria	Baireuth	1814
Asia	Bombay	Bombay	1817
Europe	Baden	Freiburg	1817
Africa	Réunion	St. Denis	1818
"	Sierra Leone	Freetown	1819
South America	Brazil	S. L. de Maranhao	1821
West Indies	St. Vincent	Langley Park	1822

Quarters.	Countries.	Towns.	Dates.
North America	Mexico	Vera Cruz	1822
Asia	Burmah	Moulmein	1823
Europe	Iceland	Reikavik	1829
Africa	Guinea	Christiansborg	1829
South America	British Guiana	Georgetown	1831
Asia	Ceylon	Kandy	1833
Africa	Egypt	Cairo	1835
"	Algeria	Algiers	1838
"	Constantine	Constantine	1838
Australia	South Australia	Adelaide	1839
"	Victoria	Melbourne	1840
"	Tasmania	Hobart	1841
Asia	Java	Buitenzorg	1841
Africa	Oran	Oran	1841
West Indies	St. Thomas	—	1842
Oceania	Tahiti	Papéiti	1846
West Indies	Barbados	Husbands	1847
Africa	Senegal	St. Louis	1848
South America	Chili	Santiago	1849
West Indies	Jamaica	Up Park Camp	1853
Asia	Persia	Ooroomiah	1853
Africa	Madagascar	Nossi-Bé	1855
South America	Venezuela	Caracas	1860
Oceania	New Caledonia	Noumea	1860
Europe	Roumania	Bucharest	1862
South America	British Honduras	Belize	1862
West Indies	Sombrero	—	1863
Asia	Cochin China	Saïgon	1864
West Indies	Porto Rico	St. John's	1868
South America	Peru	Lima	1869

EARLY RAIN GAUGES.

I have not been able to find any details respecting the gauges used in Paris by Perrault in 1668, but that at Dijon in 1674 is stated by Mariotte to have been :—

“Un vaisseau quarré qui avoit environ deux pieds de diamètre, au fond duquel il y avoit un tuyau qui portoit l'eau de la pluie qui y tomboit dans un vaisseau cylindrique.”

As regards the first English observations, those made at Townley, near Burnley in Lancashire, in 1677, it would have been very interesting to give a drawing of the gauge, but as no engraving exists, we must be content with Mr. Townley's description, which is as follows :—“I fixed a round tunnel of 12 inches diameter to a leaden pipe which could admit of no water, but what came through the tunnel, by reason of a part soldered to the tunnel itself,

which went over the pipe, and served also to fix it to it, as well as to keep out any wet that in stormy weather might beat against the under part of the tunnel; which was so placed, that there was no building near it that would give occasion to suspect that it did not receive its due proportion of rain that fell through the pipe some nine yards perpendicularly, and then was bent into a window near my chamber, under which convenient vessels were placed to receive what fell into the tunnel; which I measured by a cylindrical glass, at a certain mark containing just a pound, or 12 ounces troy, and had marks for smaller parts also."

In this description there are a few points to be noticed: (1) that Mr. Townley was careful not merely that his tunnel was firmly fixed (I have known modern observers have theirs blown away), but also that no rain could trickle down the outside of the funnel and find its way down for measurement (as has subsequently occurred). On the other hand, Mr. Townley, like most early observers, was wrong in putting the tunnel on the roof of his house; many persons would imagine that in the 27 feet of pipe there would be evaporation and loss, but from actual measurements of a similarly mounted gauge I have found this error to be almost imperceptible.

The next earliest gauge of which I have details was that used at Gresham College, London, in 1695; this is shown in Fig. 1. There is a wooden frame to support the glasses (the funnel was apparently of glass), a large bottle called a bolt-head with a neck 20 inches long, and capable of holding above two gallons. The funnel was 11·4 inches in diameter, and steadied by two stays or pack threads strained by two pins to hold the tunnel steady against the high winds. The pipe of the tunnel being no wider than $\frac{1}{4}$ of an inch, the evaporation could be but little.

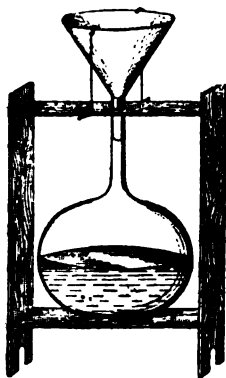


FIG. 1.

Rain Gauge used at Gresham College, London, in 1695.

The collected water was weighed every Monday morning in pounds, ounces and grains troy, and the amount was printed in that form, but the total was converted into, and printed as, the vertical depth which had fallen, viz. from August 12, 1695, to the same date in 1696, 181 lbs. 7 oz. 118 grains, or 29·11 inches.

I am not sure about the pattern of gauge used by the Rev. Mr. Derham, F.R.S., at Upminster, from 1697, but believe that it was very similar to Mr. Townley's, and similarly mounted.

As early as 1722 a close approach was made (by the Rev. Mr. Horsley, of Widdrington, Northumberland) to the modern principle. The following is the description :—

“The weighing the water and reducing it from weight to depth seemed pretty troublesome, even when done in the easiest method : to remedy this inconvenience (besides a funnel and proper receptacle for the rain) I use a cylindrical measure and gauge. The funnel is 80 inches in diameter, and the cylindrical measure exactly 8 inches, the depth of the measure is 10 inches, and the gauge of the same length with each inch divided into 10 equal parts ; or, instead of a gauge, the inches and divisions may be marked on the side of the cylindrical measure. The apparatus is simple and plain, and it is easy to apprehend the design and reason of the contrivance ; for the diameter of the cylindrical measure being just $\frac{1}{10}$ of that of the funnel, and the measure exactly 10 inches deep, 'tis plain that 10 measures of rain make an inch in depth, one measure 0.1 inch, one inch on the gauge 0.01 inch, and $\frac{1}{10}$ of an inch on the gauge 0.001 inch. By this means the depth of any particular quantity which falls, may be set down with ease and exactness, and the whole at the end of each month or year may be summed up without trouble.”

I notice, however, that in 1742 the observer at Rome, Abbot Didacus de Revillas, speaks of his gauge, which closely resembled Mr. Horsley's as “Dr. Halley's method,” so that possibly Mr. Horsley was not, after all, the originator of the pattern of rain gauge which he described.

Dr. Jurin was among the first, if not the first person, to draw up a code of rules for meteorological observers. It is not necessary to describe the rain gauge which he recommended, because it closely resembled the one just described, but it may be well to state that he is among the earliest to refer to the measurement of snow. He says : “Sextima et ultima altitudinem pluviae, vel nivis in aquam resolutæ, quæ post superiorem observationem deciderit, per digitos *Londinensis* et earum partes decimales metiatur.”

Considerable though not very satisfactory information respecting rain gauges is given in Leupold's '*Theatrum Staticum*,' folio, Leipzig, 1726. He devotes two and a half pages of text, and nine engravings to rain gauges, but his engravings are diagrams rather than drawings, and with the exception of Fig. 2 do not represent the rain gauges precisely as used.

He describes the rain gauge used from about 1717 at numerous stations by members of the Breslau Natural History Society as a sharp-edged glass funnel about 4 inches in diameter and 8 inches deep, divided to indicate the weight of water fallen into it, not the depth which it represented.

In Fig. 2 he represents a square gauge of his own design, about 9 inches square, and of which the contents were to be measured in a glass tube. Except that the upper rim should be sharp, that taps are always undesirable as they leak, and that his glass tube should have been divided to show depth, not weight, there is nothing to complain of in this, which, be it remembered was described and engraved more than 150 years since.

Leupold next describes another gauge, a square funnel leading into two glass tubes, a terrible apparatus invented by M. Leutmann, but I hope never used. He then gives a sketch which contains the germ of what is (wrongly) known as Stutter's recording rain gauge, viz. a trough with a series of compartments driven by clockwork under the orifice of a funnel, so that by measuring the fall in each compartment one would get the quantity during the respective intervals.



FIG. 2.
Leupold's
Rain Gauge.

Lastly, Leupold describes a second gauge of his own invention, which may be said to contain the germ of what is usually called Crosley's, and on the Continent (wrongly) Horner's. Leupold has under the point of his funnel a small bucket on one end of a balanced lever, when full it tips and empties, but in tipping turns a wheel one tooth, which carries a hand one division on a dial, and as there are four dials each 10 fold the other, the apparatus indicates up to 10,000 tips. There is an arrangement to prevent water passing out of the funnel while the emptying is in process. Leupold does not say that the instrument was ever tried.

In 1744 Mr. Pickering, F.R.S., proposed a gauge far inferior to that of Horsley (or Halley), and an engraving of it appears in the *Phil. Trans.* The funnel had an area of only one square inch; this led into a glass tube (of which in the engraving the diameter is exaggerated) $\frac{1}{4}$ inch in diameter, and rather more than 2 feet long. In such a tube 1 inch of rain would stand about 5 inches deep, and Mr. Pickering says that he had each inch divided into 82 parts, the marks being lead pencil on white paint. He had this hung against the railings which went round the top of his house. I am not aware that any observations made with this gauge have been preserved.

I must not, however, dwell longer upon these antiquarian curiosities, but come down to modern times and try to point out the good and the bad features illustrated by the present Exhibition. I think that this will best be done by taking seriatim various features connected with rain gauges.

DIMENSIONS.

In the Exhibition we have a drawing of the largest rain gauge ever made (No. 121), and in (No. 15) almost the smallest—one being more than two thousand times as large as the other, and yet their indications do not differ by any thing like 5 per cent. Very large gauges by radiation become cool, and being cool condense some vapour which the soil or a small gauge would not; this makes them slightly exceed small ones. But in the experiments originated by Colonel Ward and subsequently continued with the same instruments by the Rev. C. H. Griffith and the Rev. F. W. Stow, it was proved that the difference between a gauge 1 inch in diameter¹ and one five hundred times its size was less than 2 per cent. Similar comparisons have been made elsewhere, both in this country and abroad, almost always, I believe, with the same result. This, however, does not prove that either very small or very large

¹ The smallest ever used.

gauges are desirable. With gauges less than 8 inches in diameter great care in measuring is necessary, because even one drop of water represents an appreciable depth of rain. With gauges exceeding 10 inches in diameter the volume of water to be measured becomes inconveniently large and heavy, *e.g.* in the large gauge at Rothamsted 1 inch of rain must weigh more than 2 cwt. That gauge excellently fulfils its object—the measurement of small falls, and the collection of water for analysis; but no one would suggest the general use of so formidable an apparatus.

RIMS.

It was found out at a very early date that a rim round the funnel of a rain gauge was an improvement; and this is one of the points in which until a comparatively recent period there had been deterioration rather than progress. Among the gauges used in the eighteenth century (perhaps not so much in England as on the Continent) it was not at all unusual to surround the funnel with a vertical rim 6 inches high. In England, however, until the introduction of the Snowdon pattern gauge in 1864, the funnel nearly always reached *almost* to the top of the gauge. This was a pity, because if the funnel is not surrounded by a rim, if a fall of snow is accompanied by wind, hardly any of the snow will be left in the funnel; and I am afraid that most of the early English records are (for the winter months) too small, owing to insufficient attention to the measurement of snow.

I said just now *almost* to the top of the gauge, because, for nearly half a century, it has been the English practice, and is now nearly universal, that the actual top of the gauge shall be a turned brass rim. These rims deserve a word or two, because many observers buy rain gauges with bad rims. The objects of the rim are three: (1) by its solidity to keep the funnel in shape and prevent warping; (2) to define accurately the area within which rain drops are to be collected; (3) to cut any rain drop which falls upon it so that the true proportion of the drop shall go into the gauge for measurement, and the rest shall go away. As regards (1) solidity, any one can judge whether the rim is adequately firm. As regards (2) whoever verifies the gauge is responsible—and it will be a good day when the purchase of unverified gauges is abandoned. The third object is one which even opticians do not seem to understand. To cut a rain drop and send the two portions to their proper destinations a nearly vertical rim with an edge almost like that of a razor is necessary. There is a very fine specimen of what a rim should be on the gauge sent by Prof. Mascart (No. 88). See also Nos. 19 to 27. On the other hand, gauges Nos. 1, 2 and 4, which are old patterns kindly made specially for the Exhibition by Messrs. Negretti and Zambra, may be quoted as specimens of what rims should *not* be. A drop falling with driving rain on the sloping brass rim, and wholly outside of the true area of the gauge, will break into spray, and much of that spray will be blown into the gauge.

WEIGHING THE RAIN.

I have already mentioned that at Gresham College the rain was always weighed. At Townley, and at Upminster, and at many continental observatories, it was long the custom to report the rainfall by weight. I do not think that it was actually weighed, but that vessels were selected which held various fractions of a pound, and by pouring into them, the total weight was arrived at. Many of the older engravings indicate that each gauge had several measures of different sizes so as to be adapted to the amount to be measured. We have, however, seen that as early as 1722 Mr. Horsley had given up this roundabout process, and adopted a glass jar graduated in inches and decimals such as is in general use now. Weighing is now resorted to only when extreme accuracy is needed. A photograph of the Rotherham weighing machine forms exhibit No. 88.

FLOAT GAUGES.

I am not sure who first employed the rising of a float to indicate the fall of rain. I believe it is a British idea, and I do not remember having seen a float gauge on the Continent except in Breguet's Self-Recording Rain Gauge. A float was employed in a complicated gauge used at Gravesend by Mr. Kite in 1787, and three years later it seems to have been in general use, for in 1790 George Adams, Mathematical Instrument Maker to His Majesty, in "A short dissertation on the barometer, &c.," describes only one pattern of rain gauge, viz. a 12 inch contracted float; he points out the necessity for setting it to zero by putting in a little water, says that it was so arranged as to prevent evaporation, and that it was to be put in an open place where no house or other object could shelter it. In his list of prices it is marked 18s., his best Mountain Barometer being £9 9s. Further evidence in this direction is afforded by the fact that this pattern of gauge is the only one quoted in Cavallo's *Elements of Natural Philosophy*, 4 vols., 1808.

Float gauges may be divided into six classes, of which the features are : (1) uniform ; (2) contracted ; (3) rod attached ; (4) rod detached ; and as (3) or (4) may be adapted to either (1) or (2), we get the six possible varieties.

(1) Uniform, is represented in the exhibition by the small 8-inch Fleming gauge (No. 14); and it has feature (3), viz. the rod attached. This is very bad, especially with so small a gauge, because rain rarely falls vertically, and as the rain falls the float rises, and carries up the rod. Now, suppose that only $2\frac{1}{2}$ inches of rain have fallen (and this gauge is supposed to hold ten or more inches), the rod will have risen $2\frac{1}{2}$ inches above the rim, and if the rain is falling at an angle of 45° the rod will be intercepting rain, which, but for the rod, could not, and should not, be led into the gauge. Few persons would credit how serious this error is—I must, therefore, give some facts, on the authority of the *Report on the Supply of Surplus Water to Manchester, &c.* by S. C. Homersham, C.E., 1846.

In 1844 the Manchester Literary and Philosophical Society put on the hills east of the city some rain gauges which possessed the features (1) and

(8). It shortly afterwards occurred to Mr. J. Wood, who was resident engineer to the Peak Forest Canal, and near to whose residence one of these gauges was erected, that the rod must intercept much rain which ought to go over the gauge—so he had a gauge made with a cover to it, and a rod of the same size as that in the Society's gauge, *i.e.* $\frac{1}{2}$ inch diameter and 12 inches long, standing up through a hole 1 inch diameter in the centre of the said cover. The water intercepted by the stick and running down it and passing through the hole in the cover amounted to

		Ins.
1845	...	21.95
1846	...	15.40
1847	...	22.48
Mean	...	19.94

Nearly 20 inches a year. I have been told, but cannot vouch for the fact, that these faulty gauges led the Corporation of Manchester to grant compensation water far in excess of the proper amount, and which they had to buy off for £120,000.

(2) Contracted float gauges—of which Messrs. Negretti have kindly made a specimen (No. 2)—are unsafe in any country liable to frost, because the contained water, on freezing, bursts the cylinder—and as they were always made with (8) the rods attached, and their rods (owing to the contraction) rise two, three, four, or even five inches for each inch of rainfall, the error arising from these rods intercepting the rain was very serious. It is sometimes stated that these rods can be pegged or tied down—but that merely substitutes a lesser evil for the greater; if the rods are fastened down, the floats are immersed; and if the floats are immersed, the water surface is uncovered and liable to evaporation.

(4) Detached rods. Float gauges with detached rods are, in my opinion, very useful for monthly gauges, and for engineering work. If the rod is absent, it cannot be tampered with, and no one without the proper rod can read the gauge. The float nearly covers the water, and so checks evaporation. The gauge being long is sunk deep into the ground where the water is not liable to be frozen, and the gauge will hold a large quantity. If it be desired to have records true to $\frac{1}{160}$ th of an inch, all that is requisite is to contract the inner cylinder as in No. 24.

SIDE TUBE GAUGES.

We have in No. 1 a fine specimen of a pattern of rain gauge, introduced by Mr. Simms (of the firm of Troughton and Simms) in 1885, but now happily rejected. It was handy, and handsome, and if one could find a locality of which the temperature never fell below 40° or rose above 60°, a gauge of that sort would give tolerable results. It would show too little, because it is arranged to stand about 5 feet above the ground, where it would collect about 8 per cent. less than if its funnel were at the regular height of 1 ft. That, however, is its least fault. In hot weather the water in it becomes

scaldingly hot and evaporates accordingly, and in winter the water freezes and bursts both the copper body and the glass tube. Add to that the fact that taps soon corrode and begin to drip, and it will be sufficiently evident why I say that it is a pattern to be avoided.

I ought hereto refer to the continental, or perhaps I should have said, French variety of this gauge. In its early form there was no contraction, the water therefore simply rose in the tube according to the rainfall, an inch for an inch. I never saw a gauge of this pattern, but it was engraved in Pouillet's *Elémens de Physique* in 1882, and has been copied into similar works *ad nauseam*. This copying, however, has one advantage, it indicates plainly what a large proportion of most treatises on Physics consists of repetition; but that is a digression. The modern French modification of this gauge is shown in No. 89, which must be very trying to those who use it during driving snow storms. The lamp, to prevent the water in the body from freezing, must be kept alight in spite of the wind; it must give heat enough to warm the body and melt the snow, and yet not enough to send off the melted snow as vapour. Moreover it holds very little, and if it overflows the record is lost. No. 88 is a far more trustworthy gauge.

HOWARD'S GAUGES AND MODIFICATIONS THEREOF.

Howard's 5-inch funnel, bottle, and measure, are so well known that it seems almost heresy to suggest that it was not wholly original, but really there is not much room for absolute originality in a rain gauge. Dr. John Dalton, F.R.S., in his *Meteorological Observations*, 1788, does not give full details as to his rain gauge, but I think that it was a 10-inch diameter circular funnel leading into a glass bottle, and the measurement by a jar, just such as we use now. Dr. Garnett also (*Trans. R. I. Acad.* V. (1724) p. 257) used a funnel, bottle, and jar, and he represents his funnel as provided with an "umbrella," i.e. a shield to prevent rain on the *outside* of the funnel running down into the bottle and being measured. To Howard, however, I think that we are indebted for two features, of which one was entirely new, viz. the turning of the brass rim so as to ensure great accuracy as to size and shape, and also for directing attention to the importance of the horizontality of the funnel. As regards the modifications, they are set out clearly in the Catalogue Nos. 6 to 10, and 21 and 22, and therefore need not be dealt with here.

TAPS.

I do not know that taps are made better on the Continent than they are in England, or that continental climate has less effect upon out-of-door taps than is the case in England, but if neither of these conditions are true, it is difficult to understand the frequent use of taps in foreign rain gauges. In this country, after four or five years' exposure to the weather, a tap nearly always begins to drip. Are continental taps better? or do our continental friends regard the drip as trivial? I am very glad to see that Dr. Hellmann's latest pattern No. 48 has no tap, and Prof. Mascart's No. 88 has none. That almost looks as if the days of taps for rain gauges were drawing to an end.

MECHANICAL GAUGES.

As already mentioned, the first rain gauge in which the collected rain water was utilised to register its amount was designed by Sir Christopher Wren; it was a wedge-shaped bucket which, when filled to a certain height, tipped and emptied itself.

In 1725 we have a very similar arrangement shown in Leutmann's *Instrumenta Meteorognosix inserventia*.

About 100 years later, in 1827, Mr. J. Taylor¹ had a gauge made in which the water was led over a sort of water wheel with heliacal buckets; the increase of the weight of water in one bucket caused the wheel to turn until its weight became such that it passed from under the conducting tube and another took its place, each change causing a hand to advance one division over a clock-like dial.

In (or before) 1829 a gas meter maker named Crosley brought out a gauge with a modification of Sir Christopher Wren's bucket, and attached to it a train of wheels similar to those he used for gas meters, and thus we have the so-called Crosley rain gauge, of which we have three forms in the Exhibition, Nos. 80, 81 and 82. If every observer would do as one of the earliest purchasers of one (now long deceased) told me he did, Crosley gauges would not have so bad a character as they now have. My friend, the Rev. W. Steggall, of Thurston, Bury St. Edmunds, bought his Crosley gauge in 1888, and he arranged that on New Year's Eve every year a watchmaker from Bury St. Edmunds should go out to Thurston Vicarage, thoroughly clean and oil the gauge, and start it at zero for the new year, finishing up with a substantial supper and a drive back to Bury St. Edmunds. Modifications of Sir Christopher's tipping bucket enter into many patterns of self-recording rain gauges.

In (or about) 1880 this was followed by J. K. Horner's vibrating double bucket gauge, which is fully described and illustrated in Kämtz's *Lehrbuch der Meteorologie*, Vol. I. p. 412 it is nearly identical with Crosley's.

SELF-RECORDING RAIN GAUGES.

I mention these only that it may not be assumed that I have forgotten them. It is, however, quite impossible to say in this paper anything useful upon a subject to which I have already devoted more than 80 pages of different volumes of *British Rainfall*, and to which nearly another 80 pages would require to be added.

STORM RAIN GAUGES.

These are I think dealt with sufficiently in the Catalogue. See Nos. 28 and 29.

PECULIAR RAIN GAUGES.

One of the queerest rain gauges of which I have read was the De Witt gauge, of which a large number was distributed in the United States between

¹ *Phil. Mag.* Vol. II. p. 406.

1827 and 1840. As regards the State of New York, this led to the spoiling of all the rainfall work at the Academies, for when these gauges were issued the observers were told to continue their old gauges for comparison with the new ones. As far as appears from the published volume, not one of them either did that, or reported the date at which the De Witt gauge was taken into use. The De Witt gauge (first pattern) was simply a tin cone, 9 inches deep and 5 inches in diameter—it had no receiver—the water remained in the funnel (except what dried up); the funnel had no rim; we are not told how it was to be stuck up and kept level; a cone of this size would when brimful hold only 3 inches, and even with two inches a very large proportion would splash out: and the measurement was very funny, a stick was to be graduated (of course unequally) in accordance with an elaborate table, and this stick was to be plunged into the funnel with no arrangement to secure verticality, and with no correction for the displacement which the stick would produce. The second form of De Witt's gauge was even more comical. I do not know how its contents were to be measured, but it consisted of two funnels, one base upwards, as in his first pattern, the other a smaller cone, base downwards, and resting in the other cone. Anyone would be doing a service to students of American rainfall who made a list of all places to which De Witt's gauges were supplied, and of the years during which they were used.

A spherical gauge is, in my opinion, another eccentricity, for the use of which no good reason can be given, and yet so able a man as the late Dr. Robinson used one at Armagh Observatory for many years from about 1836, and Mr. J. Atkinson (whose rain map No. 102 is one of the rarest items in the Exhibition) tried one near Carlisle in 1840. I do not understand what advantage is aimed at: a ball nearly as large as the funnel was placed in it, like an egg in an egg-cup, but the outsplashing must be enormous, hail could never get in, and with snow, the whole thing would become ridiculous.

Staff gauges were another eccentricity, arising probably from Mr. Wood's experimental demonstration of the errors of float gauges with attached rods. I do not know whether he or Mr. Homersham was responsible for introducing them; the latter, however, in his *Report, &c.*, 1848, sets out the theory of the gauge, and shows that he did not understand it, because he calculates upon intercepting a strip of rain equal to half the *circumference* of his rod, whereas he would really obtain one equal to its *diameter*, which gives him an error of rather more than 50 per cent. to begin with—but in so wild a scheme that is perhaps a small portion of the total error. Possibly, I ought to give an idea of what the scheme was. A rod was to project vertically into the air, which rod passed, without touching, through a hole the sides of which were everywhere $\frac{1}{4}$ inch distant from it. The length and surface of the stick *plus* the area of the hole through which it passed were made equal to the area of a 9-inch horizontal mouthed gauge, viz. 68.61 inches. The calculations were:

Diameter of rod 2 inches ; semi-circumference 8·142

Length of rod 18·75 inches

Surface of rod = $8·142 \times 18·75 = 58·7$

Area of aperture 4·9

Total area 68·6

But evidently for the semi-circumference he should have taken the diameter, and then his area would have come out 42·4 instead of 68·6. The whole idea is, however, based on the fallacy that the rain falls ?! horizontally. Assume a vertical rain, the area exposed is less than 5 inches, and the water falling on it is to be measured by a glass adapted to a gauge more than twelve times as large. Moreover what record would a staff gauge give of a hailstorm !

METEOROLOGICAL PHOTOGRAPHY.

Abstract of an Address delivered to the Royal Meteorological Society,
on March 18th, 1891.

By ARTHUR W. CLAYDEN, M.A., F.G.S.

MR. CHAIRMAN AND GENTLEMEN,

BEFORE I show the photographs which I have brought here to-night, I wish to say a few words in explanation of the object with which they are produced.

Last year, at the Leeds Meeting of the British Association, Mr. John Hopkinson, who is familiar to most of us as a Fellow of this Society, proposed the election of a small Committee to take up the subject of Meteorological Photography. The work which had already been done by the Committee on Geological Photography had been so satisfactory, that it was felt desirable that other sciences should be given a similar chance, and thanks to Mr. Hopkinson's initiative and the cordial support he received from Mr. Symons, the task was entrusted to four of us, viz. Mr. Symons, who is our Chairman, Professor Raphael Meldola, Mr. Hopkinson and myself, the duties of Secretary falling to my share.

Now, Sir, it must occur to every one that the collection of Meteorological Photographs and the study of the applications of Photography to the purposes of our Science, is a work which this Society has carried on for some considerable time ; and indeed a glance round the walls to-night will show how keenly the importance of this work is appreciated. Some of those who are here to-night may, therefore, be disposed to think that we who compose the British Association Committee, are setting up, so to say, a rival establishment. Upon this point I had hoped that Mr. Symons might have said a word or two ; but as he has left it to me, I can assure you that there is no

thought of any such thing. When I was first asked if I would serve on the Committee, I felt that whatever results it might attain could not fail to be of advantage to Meteorology, and so of value to our Society. This view I am happy to find has been fully taken by the other Members of your Council, who have already lent us most valuable assistance. Indeed we are indebted to them for this opportunity of appealing to the Fellows for their invaluable co-operation.

Before discussing the scientific aspects of our work, perhaps I may be allowed to point out another advantage which I feel certain should follow from a development of Meteorological Photography. There are two ways of advancing a science. The first is, of course, by the discovery of new facts and new laws. Upon this I shall touch later this evening. At present I wish to emphasise the importance of the second method, which is to attract more students and diffuse that knowledge which exists. Now Meteorology is generally regarded, by what I may call outsiders, as a very "dry" subject. We ourselves know well enough the interest and value of long columns of instrumental observations. But to the uninitiated they are meaningless, or at best wearisome in the extreme. Every one, however, can appreciate the beauty or interest of a photograph, and I believe that we have an opportunity before us of enlisting very many recruits. We shall show, as the Society has already shown, that there are sections of our Science which, for general interest, will stand second to none. The observations of clouds and lightning are both subjects which every one can appreciate; and I hope that Photography may be the means of starting many people on the study of Meteorology by presenting to them the more picturesque and popular aspects of the Science. Once arouse interest, and weather charts, instrumental records and the like will be studied by the light of that interest, instead of being put aside as dry and unintelligible. Therefore, Sir, with the object of advancing Meteorology by the spread of a knowledge of its principles, we appeal to the Fellows for assistance. We ask them to send copies of any photographs they may take, either to us, or to the Council of this Society—for I take it either course will come in the long-run to much the same thing.

The collection we are making is intended for a variety of purposes. Firstly, of course, as a record of scientific facts; but also as affording the means of study and perhaps the means of teaching also. I am constantly being asked where good lantern slides can be got to illustrate lectures on meteorological phenomena, and I have always to reply that I know of no place where they can be obtained. We hope that this deficiency may be supplied by means of our collection, if only meteorologists will lend us sufficient support.

However, I must not dwell at too great length upon what I may call the popular aspect of our work. I believe it to be of very great importance, but it is most certainly second to the scientific aspect.

We hope that in time we may form a collection which will give a pictorial record of all sorts of meteorological phenomena. But we want something more than that. We want every photograph to be accompanied by a full account of the circumstances under which it was taken, and in the case of

clouds of the method adopted in its production. There are many problems of the first importance which may possibly so be solved. For instance, **what** are the relations between the various forms of clouds? How are those **various** forms produced? What relations do they bear to the distribution of **barometric** pressure? These are only a few specimen queries, none of them **have** yet been satisfactorily answered. No doubt men like the Rev. W. Clement **Ley** know a very great deal about clouds, but however complete their **knowledge** may be they cannot communicate it all to others for want of an adequate system of cloud nomenclature.

One of the first things, then, is to get together as many photographs of clouds as possible. Unfortunately, cloud photography is not easy, so a preliminary task is to find some means of simplifying the art. Heavy clouds, or clouds which stand out dark on a background of an evening sky are easy to take, but the more delicate forms of cirrus (just those about which least is known) are extremely difficult subjects for the ordinary photographer. A short exposure, correctly timed, will give a good result, but the difficulty is to get that correct time.

Various special devices have been described, such as using a slow plate, placing yellow glass in front of the lens, and so forth. We hope that some one will take up each of these methods and give it a thorough trial, such as I have given to a third. This method has been described in theory by Dr. Riggenbach so long ago as November 1888. As his paper is printed in the *Quarterly Journal*¹ of this Society it is not necessary for me to give a long description. When I first made my own apparatus I thought I had made a discovery, as Dr. Riggenbach's paper had escaped my notice, or it may be that my memory was at fault, and I conceived the same notion by what Dr. Carpenter has called "Unconscious Cerebration." This means that such credit as the method deserves must be given to Dr. Riggenbach, and the beautiful specimens of his own handiwork which are displayed in our exhibition are probably results achieved by its means. It consists in placing a mirror of black glass in front of the lens so that the plane of the mirror makes an angle of about 88° with the axis of the lens. It has long been known that some of the blue light of the sky is polarised in a certain plane, while that from a cloud is not. The mirror extinguishes the polarised light and so makes the image of the cloud stand out brightly on a dark background. This is especially the case when the cloud in question is situated about 90° from the sun, and, according to theory, the mirror should be of less and less advantage as the point of view is more and more distant from this position. As a matter of fact, I have found that the position does not greatly affect the efficiency of the mirror, its advantage being apparently due also to other causes. Being a dark mirror, it reduces the whole brilliancy of illumination, so that it becomes comparatively easy to judge the exposure correctly. The pictures of cirrus and other clouds which I show you to-night give a good idea of the value of the method, especially as I cannot lay claim to any particular skill above that of an average amateur.

¹ Vol. XV. p. 16.

Another point which these photographs illustrate is the advantage of taking a series of photographs showing either the rapidity of cloud changes, or the numerous varieties of forms assumed by cirrus clouds in a given part of the sky at intervals of a few minutes. Clouds of all kinds, cirrus, stratus, cumulus, whatever they may be, can be recorded with certainty if a little care and trouble is spent over the development of the negatives and preparation of the prints.

Clouds of course suggest rain and snow, and we hope to receive photographs showing the results of abnormal rains, such as these two records of floods at Bristol, heavy snow drifts, and even the forms of snow crystals themselves. The two slides of snow crystals I show were taken under such conditions that the image on the slide is the same size as the original snow flake. Even glaciers supply an object of great meteorological interest; for it would be most useful to have a series of pictures from a given point of view, showing the changes in the volume of a given ice-stream from year to year, and the alterations in the position of its end.

Among the photographs I have the pleasure of showing upon the screen you may notice one of a part of a solar halo. The original of this was quite invisible to the naked eye, being lost in the dazzling glare of the silvery grey sky.

Hoar frost gives innumerable beautiful objects well worthy of the camera from an artistic point of view, and well worthy of attention from the meteorologist. The photographs on the screen show plainly enough the way in which the crystals arrange themselves around the foliage of a plant, fringing the leaves, forming tassels upon thorns, and generally gathering most thickly on the smallest objects. Many of these things are still unexplained.

But perhaps the most interesting of all Meteorological Photographs are those of lightning. Here again there are many problems to be solved. We have in the possession of the Society a very fine collection of photographs of lightning, and it is indeed these pictures which have demonstrated how desirable it is to have many more. The black flashes I think I have explained. Nevertheless, I should like to see two photographs of the same flash, one black and the other white. The unsolved problems are to be found in the forms of lightning. Most of us are familiar with the broad ribbon-like flashes shown in some photographs, and with the narrow ribbons shown in others. These have been explained as due to a movement of the camera during the existence of a flash; probably many of them are, but I do not feel satisfied that all of them must be so explained.

A few photographs of electric sparks which I throw on the screen will justify this position. Sparks under given conditions tend to repeat the same form again and again, so that there seems no necessity for supposing a series of flashes should not follow similar-shaped, but not identical, paths. Again, under suitable conditions, electric discharges take the form of bright rosy pink or red discharges, each of which consists of some bright sparks, linked together by the pink or red and much less luminous discharge. These pink sparks, as I may be allowed to call them, seem to me to be the precise

analogue to some of the flashes of lightning which yield broad ribbon photographs, multiple flashes, and such pictures as Dr. Hoffert's well-known photograph.

Well, Sir, I feel that I have only given a most meagre outline of a very large subject, but I hope that outline will be enough to explain what the British Association Committee on Meteorological Photography aims at. The success which may attend its labours depends almost entirely upon the assistance of others; but if the Fellows of this Society support us as cordially as the Council, we are certain to reach some results of real and lasting value.

ON THE VARIATIONS OF THE RAINFALL AT CHERRA POONJEE IN THE KHASI HILLS, ASSAM.

By HENRY F. BLANFORD, F.R.S., F.R.Met.Soc.

(Plate VI.)

[Received November 10th, 1890.—Read April 15th, 1891.]

CHERRA POONJEE, on the southern verge of the Khasi Hills of Assam, overlooking the plains of Sylhet, has long been notorious as having a heavier rainfall than any other known place on the globe. It has already been described at some length by Mr. John Eliot in the *Quarterly Journal* of the Society for January 1882 (Vol. VIII. p. 41); but there is one feature exhibited by the registers which Mr. Eliot did not specially refer to, viz. the apparent falling off of the annual totals of the later as compared with the earlier years, and as this is a matter of some interest, and one to which my attention has long been directed, I have taken some pains to ascertain the circumstances under which the registers were kept in different years, and especially the positions of the rain-gauges. Three of the observers who contributed to these registers, viz. Dr. (now Sir Joseph D.) Hooker, Dr. (now Sir Joseph) Fayrer, and Major (now Colonel) H. H. Godwin Austen have kindly furnished me with the required information as far as regards their own work and that of the late Dr. T. Oldham, and from a fifth, the late Col. McCulloch, I obtained similar information for his contributions to the registers some time before his death. Moreover I have myself twice visited Cherra Poonjee, and have therefore some personal acquaintance with the topography of the place and the relative positions of the houses, now for the most part in ruins, at which the rain-gauges have been situated at different times. These, as far as they are certainly known, are marked on the plan of the station as it existed in 1851, which accompanies this paper. (Plate VI.)

In Mr. Eliot's paper (above referred to) is given a table of the monthly

and annual rainfall of the station for a few months of 1882, and from 1851 to 1880,¹ with the omission of the years 1855 to 1859, 1862 and 1870, for which, as far as I have been able to ascertain, the registers are no longer extant. Some other years are also imperfect. In the appendix to my own Memoir on the rainfall of India, the same table is continued up to 1886, and in that at the conclusion of the present paper it is corrected and continued up to 1888. According to the second of these tables, the mean annual rainfall of Cherra Poonjee is 474 inches; but if we take the average of only the 18 years 1876 to 1888, during which the register has been kept at the missionary station (F on the chart, Plate VI.), and where it is still recorded, it amounts to only 485 inches; whereas on the strength of the earlier registers, it was formerly given in round figures at 600 inches, and is still sometimes so quoted in meteorological treatises and handbooks. As I shall be able to show, a part of this discrepancy is undoubtedly due to a change in the site of the rain-gauge; but a portion is also due to the inclusion of the two years 1860 and 1861, the rainfall of which, according to the returns, reached the enormous figures of 700 and upwards of 900 inches respectively. Of the validity of these last, for reasons to be given presently, I am extremely sceptical. The daily registers of these years have apparently been lost; at all events I have never been able to procure them; and on a comparison of the monthly totals with those of the more authentic returns, I have but little hesitation in rejecting them. But even admitting these registers, the average rainfall of the station has been greatly over-estimated, and really but little exceeds 500 inches. Omitting them, the average of the registers extant up to the end of 1875 amounts to 468 inches, or up to the end of 1869, 504 inches, which is perhaps the most trustworthy.

The earliest published notice of the Cherra Poonjee rainfall of which I have any knowledge, is that for a few months of 1882, by Mr. Cracroft, quoted by Dr. Oldham.² In this there is nothing specially calling for remark, and I am unable to say where the rain-gauge was situated. The next notice is one by Lieut. (the late Col. Sir Henry) Yule, published in the 18th volume of the *Journal of the Asiatic Society of Bengal*, and this may be quoted at length, inasmuch as, while the authority is unquestionable, the quantity measured in the month of August 1841 exceeds that of any other single month in our existing records, with the sole and very dubious exception of

¹ I have lately ascertained that, owing to the error of a copyist, the monthly totals of the rainfall of 1869 given in the table at page 51 of Mr. Eliot's paper, and also at page 468 of the Appendix to my own memoir on the rainfall of India (Vol. III. of the *Indian Met. Memoirs*), are very erroneous. Those, however, given in the tables of daily rainfall (pages 46 to 50 of Mr. Eliot's paper) are correct. There is no record of that of the months January to April of that year, nor for December. The totals of the remaining months are:—

May	June	July	August	September	October	November
ins.	ins.	ins.	ins.	ins.	ins.	ins.
104.48	107.30	100.42	128.97	82.70	3.71	0.00

² *Geology of the Khasi Hills*, Appendix p. vi.

July 1861. The writer says: "It is with some hesitation that I write it, but the unexceptional mode of measurement, and the many times that I have seen my friend who registered the fall take these remarkable gauges, leave me no room to doubt. In the month of August 1841, during five successive days, 80 inches of rain in the 24 hours fell at Cherra; and the total fall in the month of August was 264 inches, or that there may be no mistake, 22 feet of rain. The gauge was simply a large glass jar having a funnel fitted with projecting eaves, and the water was measured morning and evening with a cylinder 8 inches in depth, of equal diameter with the funnel." Lieut. Yule does not say where the gauge was situated, but there can be little doubt that it was at one of the houses of the old and now deserted station, at one or another of which all the registers were kept up to the end of 1875.

A cursory notice of the rainfall of 1849 and 1850 is given in Dr. Hooker's *Himalayan Journals* (Vol. II. p. 282). The writer says: "Dr. Thomson and I recorded 80 inches in one day and night, and during the seven months of our stay 500 inches fell, so that the total annual fall perhaps greatly exceeded 600 inches or 50 feet, which has been registered in succeeding years. From April 1849 to April 1850, 502 inches (42 feet) fell." He further remarks: "At the Cherra station the distribution of the rain is very local, my gauges, though registering the same amount when placed beside a good one in the station, when removed half-a-mile received a widely different quantity, though the different gauges gave nearly the same amount at the end of the whole month." The house occupied by Drs. Hooker and Thomson was that marked A on the chart.¹ Sir Joseph informs me that his own register was very imperfect, owing to his frequent absence from the station, but that a regular register was kept at the same time and for some years previously by Dr. Mann, the Civil Surgeon, at the house marked B on the chart, the same that was afterwards occupied by Dr. Fayrer. This register unfortunately appears to have been lost. It was not among the records of the Calcutta Medical Office communicated to me some years since. It is not quoted by Dr. Oldham, and I have been unable to learn whether any copy of it exists elsewhere.

The register of the rainfall of 1851 and the greater part of 1852 is given in the Appendix to Dr. T. Oldham's *Report on the Geology of the Khasi Hills*, from which also is copied the chart that illustrates this paper. That of 1851 was registered partly by himself at the house marked C, partly by Dr. Fayrer at the house marked B,² and amounted to a total of 551.16 inches. That of the rainy season of 1852 was registered by Dr. Oldham at the house marked D, and that of the earlier and later months by Dr. Fletcher, the site of whose house I do not know.³ It amounted to 449.68 inches. With respect to the variation of the rainfall within short distances, Dr. Oldham's remarks confirm those of Sir J. Hooker already quoted. He says: "It may

¹ For this identification I am indebted to Sir Joseph Hooker and General Cave.

² Identified by Sir Joseph Fayrer and General Cave.

³ If, as is likely, he occupied the house vacated by his official predecessor, it would be that marked B.

be desirable to notice the extremely local distribution of much of the rain, even within such limited distances as a few hundred yards. A striking instance of this occurred to myself on the 12th October. About 4 o'clock on the afternoon of that day, I was geologising at about a quarter of a mile from the place where my rain-gauge was placed, mist and driving cloud passed over me with a few drops of rain, and continued for about 40 minutes, but scarcely sufficient to wet the light clothes I wore, and not at all such as to compel me to return home; on my return, I was greatly surprised to find that during the same time more than half an inch of rain was indicated by the gauge. At first I doubted the accuracy of this, I fancied that some accident or design had led to this result, but on the most ample and strict inquiry, I found it was not so; and that the rain, not more than 500 yards from where I had experienced only a driving mist, had come down in torrents." And again, "It is perfectly well known to the residents at the station, that some of the houses are more affected by the mist and cloud from the valleys than others, and especially those which are near to the deep valley to the east of the station. Dr. Fayrer's gauge was nearer to this valley than mine (see the map); about half way. Thus the return for September from Dr. Fayrer's table was 70·80 inches, while we had only 66·64 inches. In July Dr. Fayrer's return gave 100·85; ours gave only 96·28."

The returns from November 1852 to December 1854 are taken from a register received by the late Baron Hermann v. Schlagintweit from the Medical Office in Calcutta. It was doubtless kept by the medical officer of the station, probably Dr. Fletcher, and nothing is stated of the position of the gauge. The totals were 524·5 inches in 1853, and 552·58 inches in 1854.

The registers from 1855 to 1859, if ever recorded, have been lost, but some years ago, when all the rainfall returns then extant in the office of the Surgeon-General of Bengal were handed over to the Meteorological Office, they included the two remarkable registers of 1860 and 1861 already referred to, and a very imperfect register for 1862. Of the circumstances under which these were kept nothing is known, but there can be little doubt that the rain-gauges were throughout in some part of the old, and now nearly abandoned, station. They give a far higher rainfall than those of any other years in the table; that of 1860, deficient for the whole of November and December (which, however, are generally rainless months), amounting to 700 inches, and that of 1861, although wanting the month of March (which is scarcely ever rainless), the enormous fall of 905·12 inches, of which 886·14 inches are returned for the month of July alone. Inasmuch as this last exceeds by more than 100 inches the enormous fall of August 1841 (authen-

¹ The gauge used by Dr. Oldham is that known as Fleming's gauge, consisting of a cylindrical tube 3 ft. long, with a float carrying a graduated rod. It was placed in the centre of a small raised plot in front of the house, at an elevation to the top of the funnel of 3 feet 4 inches.

ticated by Lient. Yule), it might, standing by itself, raise some doubt of its authenticity, and since in no less than seven months of the three years¹ the monthly totals exceed the highest recorded in the corresponding months of any other year, and some others are but slightly surpassed in other years, I think there can be but little hesitation in rejecting the whole of these registers. I feel the more justified in this conclusion, that on comparing these Cherra Poonjee records with those of Sylhet for the same years, I find that the latter exhibit no similar anomalies, except perhaps in April and May 1860; and since Sylhet is situated near the foot of the Khasi Hills, little more than 20 miles distant from Cherra Poonjee, it might certainly be expected to share such remarkable rainfalls as those of the years now under consideration at Cherra.

I have been unable to ascertain the authority for the rainfall of 1868. I believe, however, that like that of the following years up to 1869 inclusive, it was received from officers of the Survey Department, who, at all events from 1864, were engaged in the survey of these and the adjacent hills. Col. H. H. Godwin Austen, who had charge of the party from 1866 to 1869, informs me that in 1864 the record was kept by Mr. N. A. Bellety, in 1865 by Capt. R. V. Riddell, R.E., and from 1866 to 1869 by himself personally or under his supervision. In the last three years the gauge was at the house marked B, and in 1865 and 1866 at that marked C in the chart. For some portions of these years Col. Godwin Austen furnished also a complete meteorological register, the only one, except that of Dr. Oldham, that we possess for Cherra Poonjee. This has been noticed by Mr. Eliot in the paper above referred to in this Journal.

In 1868, Cherra had been abandoned as a military station, and the only occupants left were the officers of the Survey party, Col. McCulloch, a retired officer in the Political Department, with one or two other private residents, and the missionaries, whose establishment lay a mile further to the north-west. At the end of 1869, it was vacated also by the Survey party, and for 1870 there is no register. In 1871, Col. McCulloch (the son of the well-known author of the *Geographical Dictionary*) volunteered his services to the Meteorological Department, and from that year to March 1876, when he removed to Shillong, he kept a regular register at the house in which he lived and which is that marked E on the chart. On leaving the station he made over the rain-gauge to the missionaries, who have since kept the register at the house marked F.

Thus we see that up to March 1876 all the registers, as far as can be ascertained, were kept at one or the other of the little group of houses immediately surrounding the church on the south, all lying within an area measuring less than half-a-mile from east to west, and less than a quarter of a mile from north to south. Indeed most of those given in the table, up to 1869 inclusive, were probably recorded at the house B on the chart; and all from 1871 to March 1876 at the house E. From April 1876 up to the present time the rain-gauge has been at F, a mile further to the north-west.

¹ In October 1860, April, May and July 1861, and January, February and March 1862.

Now on tabulating the rainfall separately for these three sites and periods, we find the following variations of the annual averages.

			Ins.		Ins.
Up to 1869, 8 to 18 years, chiefly at B			508·92	probable error	±19
1871 „ 1876,	5½ „	at E	882·98	„	±24
1876 „ 1888,	12¼ „	at F	485·22	„	±12

The periods are evidently insufficient to afford more than a very rough approximation to true averages, but at the same time the discrepancies are too great to be accounted for by the ordinary non-periodic vicissitudes of the rainfall. It is true that the year 1878, which is included in the E registers, was one of remarkably low rainfall in the province of Assam generally, as well as in many other parts of India, indeed the driest on record; the mean rainfall of the province having been 19 per cent. below the general average, and that of Bengal 81 per cent. below it. But that of 1871 was of average amount, and that of the other three years from 4 to 6 per cent. in excess, so that had the rainfall of Cherra Poonjee varied with that of the province generally, the mean of the five years would not be much more than 1 per cent. below the general average. A comparison with the registers of Sylhet and Shillong, the former, as already mentioned, 20 miles to the south, the latter 80 miles to the north of Cherra, leads to a similar result. This is shown by the following table, as far as the existing records admit of:—

Period.	Sylhet.			Shillong.		
	Mean.	Mean var.	Per cent.	Mean.	Mean var.	Per cent.
	ins.	ins.		ins.	ins.	
Up to 1869 ...	145·07	—12·26	—7·8	?	?	?
1871 „ 1875 ...	159·26	+ 1·93	+1·2	81·18	—2·57	—8·1
1876 „ 1888 ...	163·20	+ 5·87	+8·7	84·85	+1·10	+1·8

According to this table, the first period up to 1869 was one of very low average rainfall at Sylhet, but I do not think this result can be implicitly relied on, because during the greater part of this period there was no proper supervision of the registers, and some of the rain-gauges in use may have been defective. For the two latter periods the results are more trustworthy, and they show that both at Sylhet and Shillong the mean of the years 1871 to 1875 was between 4 and 5 per cent. lower than that of the years 1876 to 1888, the mean of the two stations in the former period about 1 per cent. below the general average. So far therefore the great deficiency of the E registers at Cherra Poonjee remains unaccounted for.

Nor do I know of anything in the local circumstances that will help to explain it. The rain-gauges in use at Cherra after 1870 were furnished from my own office in Calcutta, and Col. McCulloch, though not experienced as a physicist, was a man of more than average intellect, and too conscientious an observer to allow of any suspicion of neglect of his registers, though it is possible that he may have been unaware of some unrecognised source of error. There is no such difference in the position of the houses B and E as

to lead one to anticipate a great difference in the averages of the local rainfalls. Col. McCulloch's house E is but a furlong to the north of the house B occupied by Dr. Fayrer (probably Dr. Fletcher) and Col. Godwin Austen. It is nearer the margin of the plateau, and according to Dr. Oldham the nearer this was approached, the heavier was the rainfall. Col. Godwin Austen testifies to the same effect. Nevertheless, I cannot but consider that from some unexplained cause the amounts shown by the E registers were considerably below the real values.

On the other hand, the difference of the average rainfall at the missionaries' station F and the houses B, C, &c. is only such as might be expected from the position of the former, a mile to the north-west of the latter, and screened by a range of hills from the south-west. On this point Col. Godwin Austen writes: "The rainfall was much less towards the native village (half a mile to the north-west of the missionary station), and it was often clear there when raining or dense mist over the plateau."

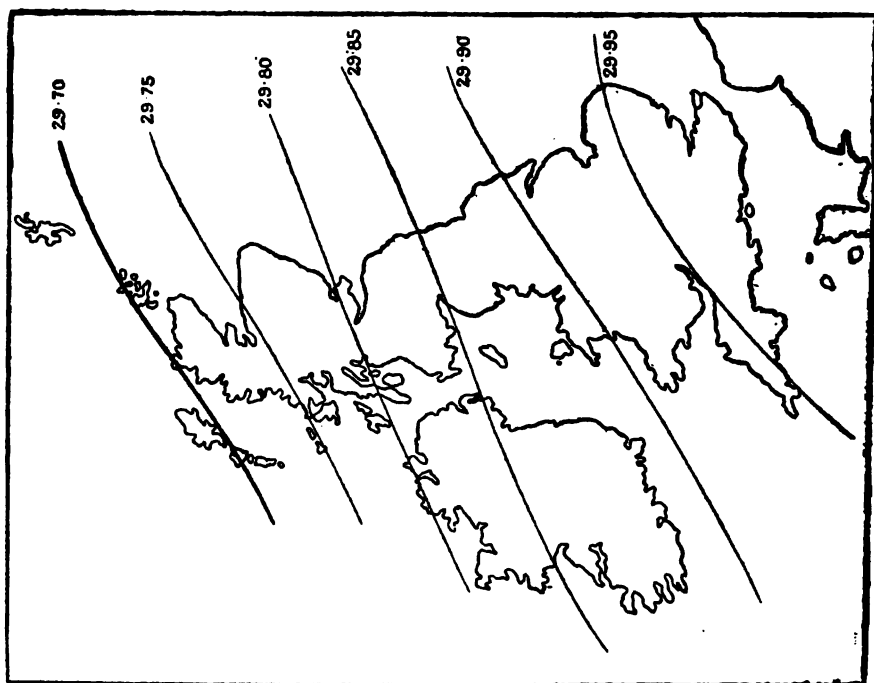
The final conclusion then at which I arrive as the result of this inquiry is that the rainfall varies very greatly in different parts of the little plateau on which the station of Cherra Poonjee is situated, and the form and position of which are shown on the map that accompanies Mr. Eliot's paper in the 8th volume of the Society's Journal. The average annual fall of the old station around the church is probably a little over 500 inches, being perhaps 5 per cent. greater near the eastern margin of the plateau than at houses about 8 furlongs distant from it. At the missionary station, a mile to the north-west, it is about 70 inches less, and on the other hand it is quite probable that it may be considerably higher further to the south in the direction of the Mausmai precipice; but there is at present no evidence that the average of any part of the plateau is so high as 600 inches, though it may amount to as much in certain wet years.

It is very desirable that further registers be obtained from some of the old sites, or from some still more southerly portion of the plateau, and now that some houses in this direction are occupied by officers connected with the inclined tramway that leads from Cherra to the foot of the hills, this may perhaps be practicable. I understand from Mr. Eliot that he hopes to be able to do this, when the results of the present inquiry are communicated to him.

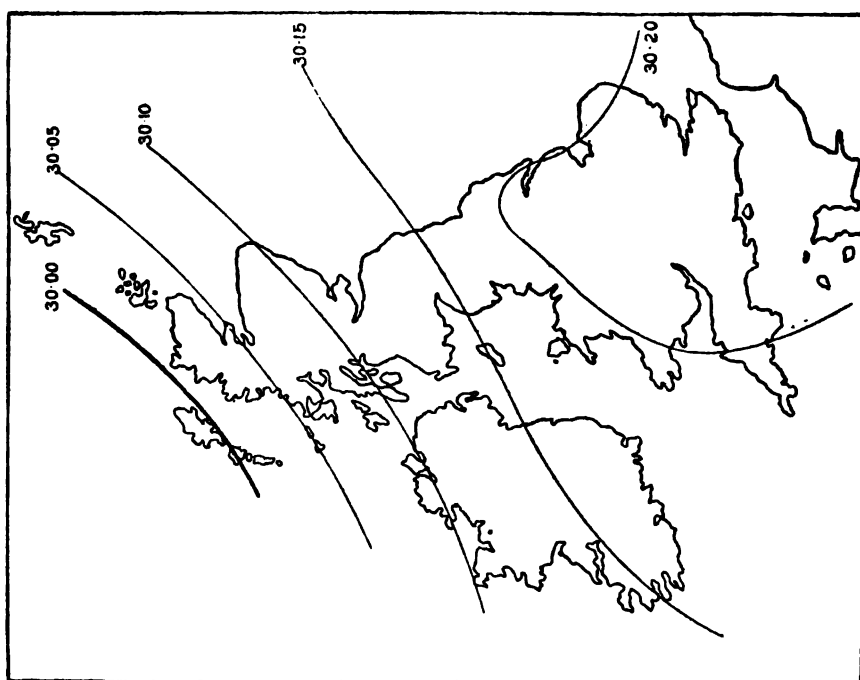
The following is a table of the monthly rainfall of Cherra, compiled from such registers as have been preserved, corrected up to the end of 1888.

RAINFALL OF CHERRA POONJEE (CORRECTED TO 1888).

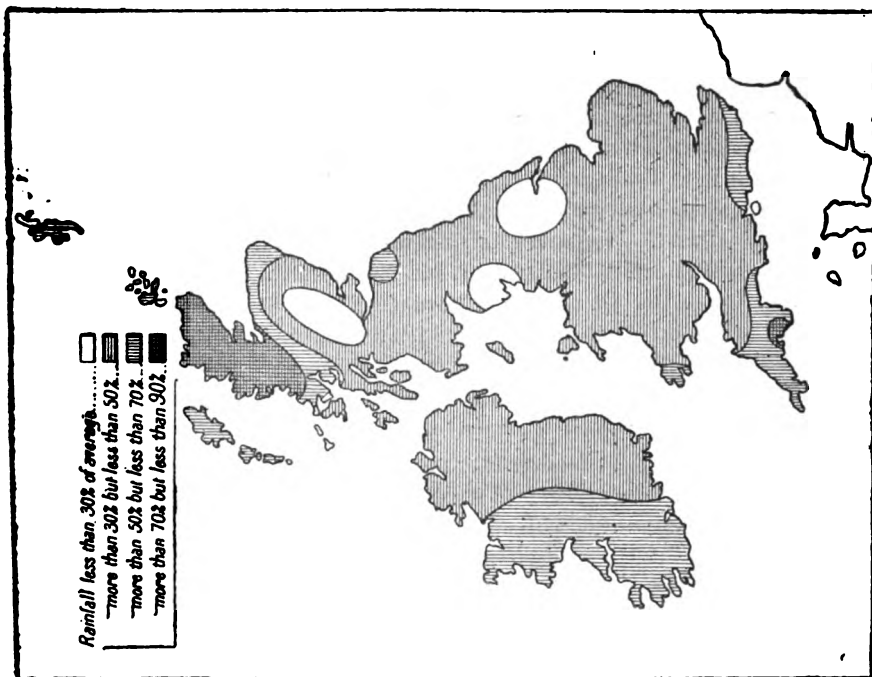
Years.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Totals.	Site of Gauge.
	Ina.	Ina.	Ina.	Ina.	Ina.	Ina.	Ina.	Ina.	Ina.	Ina.	Ina.	Ina.	Ina.	
1832	?	?	?	?	?	?	73.72	52.38	55.30	15.79	?	?	?	?
1841	?	?	?	?	?	?	?	264.00	?	?	?	?	?	?
1851	0.75	3.05	1.30	31.35	114.90	148.53	96.28	88.54	66.46	40.30	?	?	591.46	B (6 mo.) C (?)
1852	..	1.45	9.90	28.60	49.75	83.25	168.52	58.45	49.71	1.50	1.20	..	452.33	B? and D (?)
1853	0.60	..	3.45	26.50	44.20	130.85	66.80	108.45	135.15	5.25	3.35	..	524.50	B?
1854	..	3.59	6.52	33.24	10.95	146.57	141.88	140.76	23.92	31.78	13.37	..	552.58	..?
1863	?	..	..	21.80	37.03	105.09	116.23	91.58	70.75	1.20	..	..	443.68	?
1864	0.30	18.60	4.55	22.35	36.09	119.28	138.25	95.00	32.85	19.35	0.60	..	488.12	C?
1865	..	1.37	2.40	11.53	59.00	139.00	208.40	58.80	20.50	3.10	..	..	504.10	C
1866	0.85	2.88	8.18	?	20.73	94.67	122.26	58.00	38.90	23.34	?	?	?	?
1867	0.60	1.50	7.50	14.60	?	102.46	130.76	56.92	25.85	10.41	?	?	?	B (monsoon mo.)
1868	?	?	?	?	?	134.95	170.28	82.74	85.74	1.36	?	?	?	?
1869	?	?	?	?	104.48	107.20	100.42	123.97	82.70	3.71	..	?	?	?
1871	?	0.91	5.03	20.36	33.33	78.08	73.71	54.69	33.64	21.20	0.50	..	321.45	E
1872	0.51	0.35	11.59	28.95	34.61	103.65	129.05	53.54	101.49	13.72	0.37	..	477.83	..
1873	0.21	4.14	11.45	17.94	13.36	88.82	71.04	52.71	21.73	0.97	0.63	..	283.00	..
1874	1.07	4.66	10.97	28.33	96.43	64.27	115.10	45.36	47.96	8.03	0.37	..	422.55	..
1875	2.77	0.79	6.94	54.35	22.78	134.16	88.09	83.80	14.40	0.50	..	..	408.58	..
1876	..	1.63	17.57	31.91	53.86	184.80	79.37	65.02	19.43	15.76	..	..	469.35	E (3 mo.) F (9 mo.)
1877	1.16	1.14	11.10	11.76	35.19	45.59	111.07	39.30	120.05	4.87	0.10	1.07	382.40	F
1878	2.05	3.78	10.07	20.24	19.03	136.01	151.77	118.61	76.68	8.33	5.37	..	551.94	..
1879	..	0.78	0.38	10.86	84.69	134.80	106.89	90.16	45.24	11.57	..	1.75	487.12	..
1880	2.03	4.55	50.30	56.08	24.68	121.73	66.27	119.92	24.82	8.12	0.14	0.68	508.32	..
1881	..	0.37	6.29	27.37	50.20	110.83	88.75	78.53	71.04	3.16	1.35	0.02	415.61	..
1882	0.01	4.63	15.59	22.60	37.51	104.49	92.42	44.91	33.87	6.32	0.68	..	391.20	..
1883	1.28	..	4.43	14.39	67.32	84.85	67.49	65.99	56.29	..	..	3.24	371.60	..
1884	0.20	3.02	15.53	19.73	56.28	45.80	94.36	44.07	11.40	26.09	1.90	..	318.38	..
1885	0.03	0.81	8.62	24.12	25.81	85.03	107.28	55.73	127.19	6.56	1.25	0.03	442.46	..
1886	..	1.79	8.26	41.11	33.12	93.91	105.88	118.18	56.63	3.75	..	0.05	462.68	..
1887	4.28	..	20.81	28.02	47.70	192.23	38.03	57.35	48.71	3.35	..	..	440.48	..
1888	1.99	2.01	20.47	35.49	69.72	107.86	72.19	71.46	20.22	16.52	0.31	..	418.24	..



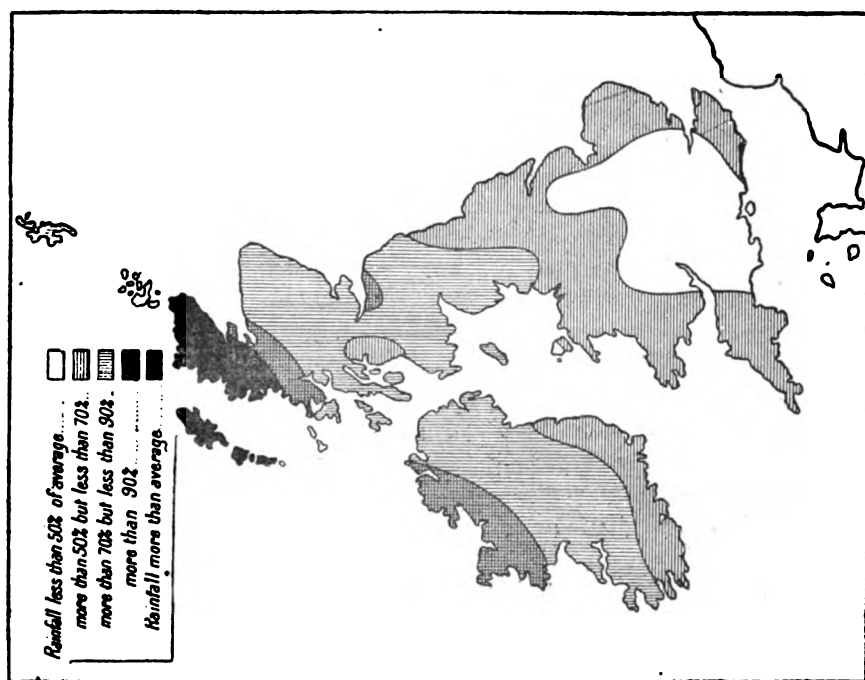
MAP. 2.
Average Winter Distribution of Mean Pressure.



MAP 1.
Distribution of Mean Pressure in the Winter of 1890-91.



MAP 3.
Rainfall over the British Islands during the Winter of 1890-91.



MAP 4.
Rainfall over the British Islands during the six months September 1890 to February 1891.

ber once in 728 years, a statement which might lead one to suppose that rainfall records existed as far back as the year 1168, which it was well known they did not. In fact, the longest record quoted by Mr. Wallis did not date earlier than 1814.

Mr. TRIPP said that he agreed with the remarks of Mr. Bayard as to the table referred to by him. As regarded Mr. Brodie's paper, he noticed that M. A. Lancaster had stated that a cold winter produced a wet summer. Mr. Stow's paper (p. 176) seemed to rather support this, for the winter of 1878-9, which was cited as being very severe, was followed by one of the wettest summers on record.

Mr. M. JACKSON said that February was certainly distinguished for lack of rainfall, but it was also remarkable for the prevalence of fog. At Ramsgate, where he had observed for 80 years, the average number of foggy days in the year was only three, but during last February 12 days of almost continuous fog were recorded. The deficiency of rainfall over the country for several months past was very great. At Tunbridge 2·60 ins. was measured during January, but the greater part of this rainfall consisted of melted snow, most of which flowed into the River Medway, causing serious floods, the surface of the ground being frozen, and so preventing any water percolating through the earth. He feared many localities, which depended upon underground water for their supply, would suffer considerably from drought during the summer months.

Mr. C. HARDING said that he had made a comparison between Tables I. and IV., in Mr. Brodie's paper, and had found that when the barometric pressure was below the average the rainfall was above the average, the only exceptions being 1871-2 and 1886-7. He had also examined Hoffmeyer's Charts in order to ascertain whether the same conditions prevailed over the Atlantic when severe weather was experienced over the British Isles, but had found that the distribution of pressure and general conditions were very dissimilar. For instance, in 1881, when very intense frost prevailed over our Islands during January, the conditions prevailing over the Atlantic were in no way similar to those which existed during the winter of 1890-91. Regarding the prolonged character of the cold weather during the past winter, he believed that, supposing that the months of April and May of the present year proved to be of average temperature, the mean temperature of the period, September 1890 to May 1891, would not be so low by about 2° as was that of the similar period in 1887-8, the mean of which was 42°. A study of the charts issued by the Hydrographic Office of the United States shows that the North-east Trade Wind was completely reversed, while in a paper recently read before a French Scientific Society it was stated that the rainfall during February in Algeria had been exceedingly heavy, so that it had not been possible to sow any seeds. There had been less fog than usual in the Atlantic during the past winter, but in the British Islands considerably more fog had prevailed than was generally experienced. Icebergs, too, had been more frequently encountered in the Atlantic recently than was generally the case. The distribution of isobars over England did not give any clue as to the cause of the severe cold experienced during last winter, and it was necessary to greatly extend the area of inquiry in order to fully investigate the cause of such severe seasons as that described in Mr. Brodie's paper.

Mr. SOUTHALL said that he wished that the period covered by Mr. Brodie's paper had been extended, as he considered the months of December, January, and February formed a rather arbitrary winter. In the neighbourhood of Ross the drought had now extended over 21 months. He thought it was not possible to forecast the character of the coming summer, and showed that the supposition that a severe winter was usually followed by a wet summer was incorrect.

Mr. BRODIE, in reply to Mr. Harding, said that from an examination of the distribution of mean pressure it is clear that the trend of the isobars over England during the past winter was distinctly anticyclonic, so that a very ready explanation was afforded of the intense cold which prevailed in that country. Over Ireland and Scotland the isobars had, on the other hand, a distinct cyclonic tendency, and as a matter of fact the frost in those countries was comparatively slight. With regard to Mr. Southall's objection, the months of December to February were commonly taken to represent the winter, and if the year were to be divided into four seasons of equal length no other definition was possible. A long experience had fully convinced him that the character of any particular season afforded no reliable guide as to the weather which might follow.

Mr. WALLIS, in reply, said that the figures to which Mr. Bayard took exception were qualified by the expression, "Accepting the results given by the table," but although the 728 years were not consecutive they were the best available, and gave a long mean. He believed that though the values could not be considered as exact, they gave a close approximation to the relative frequency of such a small rainfall in the different months of the year.

THE RAINFALL OF FEBRUARY 1891.

By H. SOWERBY WALLIS, F.R.Met.Soc.

[Received April 1st.—Read April 15th, 1891.]

RAINFALL being expressed in figures, my paper is essentially a collection of tables, and letterpress is needed only to point out their salient features. I have put in rather full tables as evidence of the facts, and have made notes of what appear to me the most important results.

I have prepared a Table¹ which contains returns from 521 stations, being practically all that I could obtain, excepting a few monthly records from gauges in Wales and the Lake district, these gauges and the time of observation not being sufficiently precise to be of value for the discussion in hand.

The stations are arranged from south to north in their respective counties, and the counties are arranged in the order adopted by the Registrars-General. This order is the same as that used in *British Rainfall*, and will therefore probably be that most familiar to rainfall observers.

The 521 stations are for all the calculations of the paper reduced to 515, six (marked with an *) being omitted, as they evidently include rain which properly belongs to January, but which was entered to the wrong day. Of these stations 385 are in England, 82 in Wales, 52 in Scotland, and 46 in Ireland.

Assuming that the average of these stations fairly represents the mean fall over the different countries, we have for England an average total for the month of only 0.180 in., but if we exclude the Lake District, *i.e.* Cumberland, Westmoreland, and North Lancashire, where the fall at several stations exceeded an inch, we have a fall over the remainder of the country of only 0.066 in., or about one fortieth of the average.

At 284 stations, or 74 per cent of the whole number, the rainfall did not exceed 0.10 in., while at 50, or 13 per cent. of the stations, no rain was recorded.

As regards the distribution over the different counties, the data available are set out in Table I. They are however insufficient to give complete information, as several counties are represented by only one station, and some are not represented at all.

Those for which we have sufficient data are :—

Not printed herewith.

County.	Mean Rainfall.	County.	Mean Rainfall.
	In.		In.
Middlesex	·004	Suffolk	·059
Cambridge	·029	Kent	·065
Hertford	·080	Northampton	·071
Gloucester	·088	Hampshire	·075
Surrey	·086	York	·100
Sussex	·042	Cornwall	·162
Norfolk	·058		
Devon	·058	Lancashire	·488

The only counties with a mean rainfall of more than ·10 in. are :

County.	Mean Rainfall.	County.	Mean Rainfall.
	In.		In.
*Shropshire	·105	*Cheshire	·182
*Leicester	·110	*Derby	·280
*Lincoln	·144	Lancashire	·488
Cornwall	·162	Cumberland	·726
*Warwick	·170	Westmoreland	1·001

The mean for Derby is greatly raised by a large fall in the Peak district, and for Lancashire, by that in the hill district in the north, the mean for the southern half of the county being only ·166 in.

The counties from which no reports exceeding ·10 in. have been received are Middlesex, Surrey, Hertford, Buckingham, Oxford, Huntingdon, Bedford, Cambridge, Wilts, Dorset, Somerset, Hereford, Worcester, and Rutland, while those from which no station reports so small a fall as ·10 in. are Warwick, Cheshire, Cumberland, and Westmoreland.

By grouping the counties into the divisions adopted by the Registrar-General, we get a sufficient number of stations in each to give very reliable means, which are given in Table I. and summarised in Table II.

In this method of comparison Middlesex, as Division I, again carries off the palm with its mean rainfall of ·004 in., all its stations reporting less than ·10 in., and 57 per cent. of them ·00 in. Division III., South Midland Counties, comes next with a mean rainfall of ·088 in., 95 per cent. of its stations not exceeding ·10 in., and 22 per cent. reporting ·00 in. These two are the only divisions with a mean rainfall of less than ·05 in. Then follows Division IV., Eastern Counties, mean rainfall ·054 in.; 87 per cent. of the stations not exceeding ·10 in., and 11 per cent. reporting ·00 in.; Division VI., West Midland Counties, mean rainfall ·057 in., 88 per cent. of the stations not exceeding ·10 in., and 10 per cent. of ·00 in.; Division II., South Eastern Counties, mean rainfall ·058 in., 85 per cent. of the stations not exceeding ·10 in., and 17 per cent. with ·00 in.; Division V., South Western Counties, mean rainfall ·072 in., 79 per cent. of the stations not exceeding ·10 in., and

* For these counties the number of returns is too small to give a thoroughly reliable mean.

TABLE I.

MEAN RAINFALL OF THE COUNTIES AND DIVISIONS, FEBRUARY 1891.

County and Division.	No. of Stations.	Mean Rainfall.	No. of Records not exceeding 0.10 in.	No. of Records of 0.00 inch.	County and Division.	No. of Stations.	Mean Rainfall.	No. of Records not exceeding 0.10 in.	No. of Records of 0.00 inch.
I.		In.			X.		In.		
Middlesex	7	·004	7	4	Durham	5	·056	4	0
Division	7	·004	7	4	Northumberland ..	9	·094	6	0
II.					Cumberland	16	·726	0	0
Surrey	9	·036	9	2	Westmoreland	9	1·001	0	0
Kent	17	·065	15	2	Division	39	·558	10	0
Sussex	9	·042	9	3	XI.				
Hants	13	·075	8	1	Monmouth	3	·033	3	1
Division	48	·058	41	8	Glamorgan	2	·095	1	0
III.					Cardiff	2	·250	0	0
Herts	25	·030	25	5	Pembroke	3	·143	1	0
Bucks	1	·000	1	1	Cardigan	3	·230	1	0
Oxford	4	·013	4	2	Brecknock	2	·180	1	0
Northampton ..	21	·071	17	0	Radnor	3	·150	1	0
Hunts	1	·000	1	1	Montgomery	3	·250	1	0
Bedford	5	·004	5	4	Merioneth	2	·345	1	1
Cambridge	19	·029	19	4	Carnarvon	3	·100	1	0
Division	76	·038	72	17	Anglesea	1	·280	0	0
IV.					Isle of Man	1	·240	0	0
Essex	7	·049	6	1	Scilly	1	·020	1	0
Suffolk	8	·059	6	1	Jersey	2	·055	2	0
Norfolk	40	·053	36	4	Guernsey	1	·060	1	0
Division	55	·054	48	6	Division	32	·170	15	2
V.					XII.				
Wilts	5	·014	5	1	Southern Counties	5	·344	1	0
Dorset	6	·013	6	3	XIII.				
Devon	28	·058	24	3	S.E. Counties	4	·478	0	0
Cornwall	14	·162	6	0	XIV.				
Somerset	4	·018	4	1	S.W. Counties	4	·475	0	0
Division	57	·072	45	8	XV.				
VI.					W. Mid. Counties	8	2·824	0	0
Gloucester	23	·033	22	4	XVI.				
Hereford	3	·037	3	0	E. Mid. Counties	7	·831	0	0
Shropshire	2	·105	1	0	XVII.				
Stafford	4	·098	2	0	N.E. Counties	6	·897	0	0
Worcester	6	·058	6	0	XVIII.				
Warwick	3	·170	0	0	N.W. Counties	10	3·294	0	0
Division	41	·057	34	4	XIX.				
VII.					Northern Counties	8	2·468	0	0
Leicester	3	·110	1	0	XX.				
Rutland	2	·070	2	0	Cork	4	·648	0	0
Lincoln	5	·144	1	0	Kerry	4	·745	0	0
Notts	3	·093	2	0	Waterford	1	·330	0	0
Derby	5	·230	1	0	Tipperary	2	·350	0	0
Division	18	·146	7	0	Limerick	1	·180	0	0
VIII.					Clare	4	·367	0	0
Cheshire	4	·182	0	0	Division	16	·516	0	0
(S. Lancashire)	(8)	(·166)	(3)	(0)	XXI.				
Lancashire	15	·488	3	0	Wexford	1	·240	0	0
Division	19	·424	3	0	Carlow	1	·280	0	0
IX.					King's County	1	·180	0	0
Yorkshire	25	·100	17	3	Dublin	1	·040	1	0
Division	25	·100	17	3	Westmeath	2	·270	0	0

TABLE I.

MEAN RAINFALL OF THE COUNTIES AND DIVISIONS, FEBRUARY 1891.—*Continued.*

County and Division.	No. of Stations.	Mean Rainfall.	No. of Records not exceeding 0·10 in.	No. of Records of 0·00 inch.	County and Division.	No. of Stations.	Mean Rainfall.	No. of Records not exceeding 0·10 in.	No. of Records of 0·00 inch.
Longford	1	·220	0	0	XXIII.		In.		
Division	7	·214	1	0	Cavan	1	·260	0	0
XXII.					Down	4	·222	0	0
Galway	4	·473	0	0	Antrim	3	·307	0	0
Mayo	2	·710	0	0	Londonderry	1	·250	0	0
Sligo	2	·380	0	0	Tyrone	2	·550	0	0
Leitrim	1	·550	0	0	Donegal	3	·413	0	0
Division	9	·513	0	0	Division	14	·388	0	0

14 per cent. with ·00 in. The remaining Divisions all had a mean rainfall exceeding ·10 in.

The Welsh returns are set out like the English ones in counties, but owing to the paucity of stations and the very varied physiography of the country, it is useless to deal with the counties individually. The 82 stations give a mean fall of ·170 in., 15 stations or 47 per cent. report falls not exceeding ·10 in., while 2 or 6 per cent. report no rain. It is difficult to form any idea of the mean rainfall over such a country as Wales, but probably this ·170 in. is not more than one twentieth of the average for the month.

In Scotland, as in Wales, the physical features vary greatly even in a single county, and the rainfall there though small was not phenomenally so. I have therefore in Table I. given only the totals for each division. For the present purpose the country may be divided into two fairly equal parts, the east and south, where there was a great deficiency: and the west and north, where the fall was normal.

The east and south comprises Divisions XII., Southern Counties; XIII., South Eastern Counties; XIV., South Western Counties; XVI., East Midland Counties; and XVII., North Eastern Counties. Reports have been received from 26 stations, and give a mean rainfall of ·644 in.: only one station reports less than ·10 in., and not one ·00 in. The mean though small is not unprecedented and is probably about one fifth of the average for the month.

The west and north comprises Division XV., West Midland Counties; Division XVIII., North Western Counties; and Division XIX., Northern Counties. The number of returns is 26, the mean rainfall 2·895 ins., and no station reports less than ·10 in., in fact only one station had less than an inch, while the largest record is 8·78 ins. This part of the Kingdom probably had about three fourths of the average.

Taking Scotland as a whole, the 52 stations give the very respectable mean fall of 1·769 in.

TABLE II.

MEAN RAINFALL AND NUMBER OF STATIONS AT WHICH THE FALL DID NOT EXCEED
0·10 IN., AND AT WHICH NO RAIN WAS RECORDED DURING FEBRUARY 1891.

Division.	Number of Stations.	Mean Rainfall.	Stations with Rainfall not above ·10 in.		Stations with no rain.	
			Number.	Per cent. of Total Number.	Number.	Per cent. of Total Number.
ENGLAND.			In.			
I. Middlesex	7	·004	7	100	4	57
II. South Eastern Counties	48	·058	41	85	8	17
III. South Midland "	76	·038	72	95	17	22
IV. Eastern "	55	·054	48	87	6	11
V. South Western "	57	·072	45	79	8	14
VI. West Midland "	41	·057	34	83	4	10
VII. North "	18	·146	7	39	0	0
VIII. " Western "	19	·424	3	16	0	0
VIII. Exclusive of N. Lancashire	(12)	(·172)	(3)	(25)	(0)	(0)
IX. Yorkshire	25	·100	17	68	3	12
X. Northern Counties	39	·558	10	26	0	0
X. Exclusive of Cumberland and Westmoreland.... }	(14)	(·081)	(10)	(71)	(0)	(0)
England	385	·130	284	74	50	13
" exclusive of the Lake District }	353	·066	284	80	50	14
XI. Wales, Monmouth, &c.	32	·170	15	47	2	6
SCOTLAND.						
XII. Southern Counties	5	·344	1	20	0	0
XIII. South Eastern "	4	·478	0	0	0	0
XIV. " Western "	4	·475	0	0	0	0
XV. West Midland "	8	2·824	0	0	0	0
XVI. East "	7	·831	0	0	0	0
XVII. North Eastern "	6	·897	0	0	0	0
XVIII. " Western "	10	3·294	0	0	0	0
XIX. Northern "	8	2·468	0	0	0	0
Scotland	52	1·769	1	2	0	0
" E. & S. half	26	·644	1	4	0	0
" W. & N. "	26	2·895	0	0	0	0
IRELAND.						
XX. Munster	16	·516	0	0	0	0
XXI. Leinster	7	·214	1	14	0	0
XXII. Cannought	9	·513	0	0	0	0
XXIII. Ulster	14	·388	0	0	0	0
Ireland	46	·414	1	2	0	0
" Western half	25	·514	0	0	0	0
" Eastern "	21	·293	1	5	0	0

Adhering to the Divisions of the Registrar-General, Ireland, like Scotland, may be conveniently divided into halves—Munster and Connaught in the west; and Leinster and Ulster in the east: the western half being naturally the wetter.

From Munster and Connaught, 25 stations give a mean rainfall of half-an-inch (·514 in.), and no record so small as ·10 in.

From Leinster and Ulster, 21 stations give a mean rainfall of ·293 in., and one station (Dublin) reports less than ·10 in. (·04 in.).

These two mean falls of ·514 in. and ·293 in. bear very nearly the same relation to the average of the two portions of the Kingdom in which they

occur. The mean for the whole country based on the 46 stations is $\cdot414$ in., which is about an eighth of the average for the month.

A better idea of the fall over Ireland may be obtained by ignoring the boundaries of the provinces, and even to a certain extent the boundaries of the counties, when we find, as might be expected, that the fall increases steadily from east to west. The returns from the counties on the east coast give a mean of $\cdot20$ in., those from the centre and north of the country a mean of $\cdot85$ in., while the mean for the west and south-west is $\cdot60$ in.

In Table III. I have given the rainfall returns for 20 continental stations, distributed over the west of Europe from the Mediterranean to Sweden; at only 8, (Nice, $\cdot95$ in.; Munich, $\cdot56$ in.; and Stockholm, $\cdot51$ in.) did the fall exceed half-an-inch, while at 6 it was less than $\cdot10$ in.

	In.
Lorient	$\cdot00$ on 0 days
Lyons	$\cdot04$ „ 1 „
Belfort	$\cdot04$ „ 1 „
Brest	$\cdot04$ „ 1 „
Wiesbaden	$\cdot04$ „ 1 „
Rochefort	$\cdot08$ „ 2 „

M. A. Lancaster states in *Ciel et Terre*¹ that in the month of February the mean total rainfall for the whole of Belgium was only $\cdot16$ in.

TABLE III.

RAINFALL AT CONTINENTAL STATIONS IN FEBRUARY 1891.

Station.	Rain.	No. of days.	Station.	Rain.	No. of days.
	In.			In.	
Biarritz	$\cdot12$	2	Wiesbaden	$\cdot04$	1
Perpignan	$\cdot24$	2	Brussels	$\cdot16$	5
Nice	$\cdot95$	1	Cape Gris Nez	$\cdot16$	3
Lyons	$\cdot04$	1	Berlin	$\cdot32$	4
Rochefort	$\cdot08$	2	The Helder	$\cdot28$	3
Belfort	$\cdot04$	1	Cuxhaven	$\cdot40$	4
Lorient	$\cdot00$	0	Copenhagen	$\cdot47$	3
Brest	$\cdot04$	1	The Skaw	$\cdot35$	3
Munich	$\cdot56$	6	Stockholm	$\cdot51$	3
Paris	$\cdot12$	2	Christiania	$\cdot39$	5

Precise comparison of February 1891 with previous exceptionally dry months is difficult, owing to the fact that before the foundation of the Rainfall Organisation in 1860 the same precision was not observed with regard to small falls of rain, or to the measurement of snow. The number of stations also was very limited.

Table IV. contains all records of months with a total rainfall not exceeding a quarter of an inch at 12 stations fairly distributed over the British Isles, whose records extend over an aggregate period of 728 years, or an average of 61 years. The records are not all absolutely continuous, but I have used

¹ Vol. XII. p. 45.

much care in selecting them, and the two stations at Cork are the only case in which there was any material difference in the position of the two gauges. Every entry in the table has been compared with, and is thoroughly substantiated by, the records of neighbouring gauges.

This table indicates that, speaking of the British Isles as a whole, a month with not more than a quarter of an inch of rain will occur once in 9 years. But when we examine the stations individually we come upon, what is to me, a new phenomenon in rainfall statistics. The frequency of the occurrence of such a dry month varies from once in 8·6 years at Boston to once in 60 years at Orleton. This variation is enormous, and at once suggests inaccuracy, but I can find no error. The 8·6 at Boston is supported by 4·5 at Exeter and 5·7 at Cork. The Exeter Institution record, extending over 74 years, gives 1 in 8·9, and the record at Spalding, Pode Hole, extending over 62 years, agrees very closely with that at Boston. The Orleton value of 1 in 60 years is supported by Haverfordwest with no record in 42 years, but Haverfordwest has a mean annual rainfall of nearly 50 ins., while Orleton has a mean of about 80 ins., practically the same as Exeter.

Accepting the results given by the table, and examining them with respect to monthly frequency, we find that they group themselves in the following order:—

May with a rainfall not exceeding ·25 in., once in 84·7 years					
April	„	„	„	52·0	„
June	„	„	„	60·0	„
February	„	„	„	104·0	„
March and December	„	„	„	121·8	„
September	„	„	„	145·6	„
January	„	„	„	242·7	„
July, August, and October	„	„	„	864·0	„
November	„	„	„	728·0	„

The place which February takes in the table is in a great measure due to its shortness, and in the month under discussion, February 1891, the result would be very different if we added one day at each end, for at many stations rain was recorded both on January 31st and on March 1st.

Two of the driest months in recent times in England and Wales were September 1865 and June 1887, but neither of these bear comparison with February 1891.

In September 1865, out of a total of 770 stations, 129, or 17 per cent., recorded less than ·10 in.; and 48, or 6 per cent., no rain.

In June 1887—101 stations, at 9, or 9 per cent., the fall did not exceed ·10 in., and at 2, or 2 per cent., no rain was recorded.

In February 1891—885 stations, at 284, or 74 per cent., the fall did not exceed ·10 in., and at 50, or 13 per cent., no rain was recorded.

On page 157 of *British Rainfall* 1887, I find with reference to June of that year:—“In the South Western Counties, with an average annual rainfall varying from 80 ins. to about 100 ins., the deficiency was exceptionally great,

TABLE IV.

TABLE OF MONTHLY RAINFALLS NOT EXCEEDING 0·25 IN.

Stations.	January.		February.		March.		April.		May.	
	In.		In.		In.		In.		In.	
Chichester, Chilgrove	·00	1840	·16	1854	·21	1880
Exeter, St. Thomas's	·00	1855	·19	1887	·06	1840	·00	1817	·10	1814
and Manston Terrace	·22	1854	·10	1844
.....	·20	1861	·24	1871
Tenbury, Orleton	·15	1870	..	..
Boston and Grand	·12	1826	·12	1832	·17	1829	·20	1852	·22	1829
Sluice	·21	1880	·22	1849	·12	1830	·23	1855	·18	1848
.....	·25	1858	·25	1856	..	..	..	..
Bolton, The Folds	·05	1858	..	..	·00	1842	·18	1836
.....	·20	1844
York, Bootham and	·16	1832	..	..	·18	1855	·21	1836
Phil. Soc.	·24	1861	..	..
Haverfordwest
Pentland Hills, Glen-	·10	1856	·00	1842	·10	1859
corse	·05	1854	·07	1836
.....	(·22 ¹)	1877	..	..	..	..	·10	1839
Cork, Royal Institu-	(·27 ²)	1888	..	..	..	..	·14	1844
tion and Blackrock	·02	1861
.....	·15	1874
Dublin, Phoenix Park	·10	1876
Collooney, Markree
Obs. and Sligo	·24	1836
Mount Shannon	·14	1844
Belfast, Linen Hall	·17	1842	·23	1824
and Queen's College	·25	1836
.....	·19	1859
Total	..	3	..	7	..	6	..	14	..	21
Frequency 1 in.	..	242·7	..	104·0	..	121·3	..	52·0	..	34·7

Stations.	June.		July.		August.		September.		October.	
	In.		In.		In.		In.		In.	
Chichester, Chilgrove	..	..	..	..	..	..	·00	1851	..	..
Exeter, St. Thomas's	·13	1870	·00	1825	·07	1818	·03	1865	..	..
and Manston Terrace	·06	1887	..	..	..	..	..	..	..	..
.....	·21	1889	..	..	..	..	..	..	..	..
Tenbury, Orleton	..	..	..	..	..	..	·11	1865	..	..
Boston and Grand	·21	1826	..	..	·15	1861	..	..	..	..
Sluice	·16	1887	..	..	..	..	..	..	..	..
Bolton, The Folds	..	..	..	..	..	..	..	..	..	..
York, Bootham and	·16	1887	..	..	..	..	·23	1865	·20	1834
Phil. Soc.	..	..	..	..	..	..	..	..	..	..
Haverfordwest	..	..	..	..	..	..	..	..	..	..
Pentland Hills, Glen-	..	..	..	..	..	..	..	..	..	..
corse	..	..	..	..	..	..	..	..	..	..
Cork, Royal Institu-	·13	1826	..	..	..	..	..	..	·24	1840
tion and Blackrock	·06	1869	..	..	..	..	..	..	..	..
Dublin, Phoenix Park	·15	1887	..	..	..	..	·10	1865	..	..
Collooney, Markree	·10	1889	..	..	..	..	..	..	..	..
Obs. and Sligo	·14	1887	·23	1863	..	..	..	..	..	..
Mount Shannon	..	..	..	..	..	..	..	..	..	..
Belfast, Linen Hall	·07	1821	..	..	..	..	..	..	..	..
and Queen's College	..	..	..	..	..	..	..	..	..	..
Total	..	12	..	2	..	2	..	5	..	2
Frequency 1 in.	..	60·7	..	364·0	..	364·0	..	145·6	..	364·0

¹ Incorrect, not included.

TABLE IV.

TABLE OF MONTHLY RAINFALLS NOT EXCEEDING 0·25 IN.—*Continued.*

Stations.	November.		December.		No. of Years' Record.	No of in- stances.	Frequency. Years.
	In.		In.				
Chichester, Chilgrove	57	5	11·4
Exeter, St. Thomas's and Manston Terrace	·12	1879	..	..	77	17	4·5
Tenbury, Orleton	60	1	60·0
Boston and Grand Sluice	·20	1829	65	18	3·6
	·27	1835	..	..	..
	·12	1843	..	..	..
Bolton, The Folds	·22	1844	60	5	12·0
York, Bootham and Phil. Soc.	·22	1843	60	8	7·5
Haverfordwest	42	0	..
Pentland Hills, Glencorse	·20	1844	61	4	15·3
Cork, Royal Institution and Blackrock	63	11	5·7
Dublin, Phoenix Park	54	3	18·0
Collooney, Markree Obs. and Sligo, Mount Shannon	58	4	14·5
Belfast, Linen Hall & Queen's College	71	5	14·2
Total	1	..	6	728	81	9·0
Frequency 1 in.....	..	728·0	..	121·3	..	..	..

and probably the following list of stations, which report no measureable quantity of rain in the whole of the calendar month, is one of the most remarkable tables in the annals of rainfall work :—

County.	Station.
Devon	Starcross, Powderham Castle.
"	Rousdon Observatory (monthly gauge).
"	Exeter Institution.
"	Hatherleigh, Winsford.
Cornwall	Probus Lamellyn.
"	Par Station, Penellick.
"	Liskeard, St. Cleer.
"	Bude.

It is rather curious that this table contains exactly the same number of stations in the South Western Counties reporting no rain, as I have in my present tables, but no doubt when the whole 8,000 returns for 1891 are worked up the 8 will be increased to 16 or more.

The effect of such a month as February on the water supply of the country is difficult to realise, the deficiency may be roughly taken at

250 tons per acre over the whole of	England.
800 " " " "	Wales.
150 " " " "	Scotland.
800 " " " "	Ireland.

I have said nothing about the number of rainy days. I feel that in the present case they are more an indication of personal equation than of anything else. A zealous observer finds in his gage a quantity of about $\cdot 005$ in., he resists the temptation to throw it away, and with the spirit of a martyr enters a fall of rain and a rainy day. Another, equally zealous and conscientious, gives the month the benefit of the doubt, and produces triumphantly a blank record. Even at the headquarters of British Rainfall the only entry during the month, $\cdot 01$ in. on the 7th, was suspended till the reading of the weekly gage should decide whether it was to be entered or not.

“ SOUTH-EAST FROSTS,”

WITH SPECIAL REFERENCE TO THE FROST OF 1890-91.

BY REV. FENWICK W. STOW, M.A., F.R.Met.Soc.

[Read April 15th, 1891.]

THIRTY years ago and more, when I first began to take Meteorological Observations in Yorkshire, I noticed that while frost usually came with North and North-east winds, it sometimes came with South-east winds. In the latter case I found that there was little fear of the skating being spoilt by snow; the frost was sure to be sharp while it lasted, but it was not likely to last long.

The first of these South-east frosts which I noticed, and of which I kept a register, was in December 1855. The frost of last winter, which was also a South-east frost till the end of December, seemed therefore quite like an old friend to me.

I have extracted from my register some particulars about all the frosts, beginning with 1855, which I believe to have been of this character.

I may be mistaken about some of them. It often happens that what is evident at the time to an observer is not so evident when studied in a record. I have, however, a clear recollection of most of these frosts, and I trust that my list is fairly correct. I am somewhat doubtful about the frosts of 1870, for reasons which I give in a note.¹

¹ In 1870 I was at Hawsker, near Whitby. On the sea coast meteorological conditions are subject to much local variation. Great precipitation often occurs on the coast when fine and dry weather is prevalent inland. Moreover, the direction of the wind at a coast station is locally affected both by the character of the coast, which often makes it easier for the wind to blow *along* it rather than across it, and also by the differences of temperature between sea and land, which tend to make the wind blow from whichever is the colder.

LIST OF "SOUTH-EAST FROSTS" OBSERVED IN YORKSHIRE.

Place.	Year.	Date of com- mencement of Frost.	Duration. Days.	Temperature.			General Direction of Wind.	
				Lowest Min.	Date.	Lowest Max. Date.		
Red Hall, near Leeds	1855	Dec. 18	6	18°0	21st	24°0	21st	SE
"	1858	Jan. 1	8	23°3	5th	29°5	6th	ESE
"	1861	Dec. 24	8	23°0	30th	34°0	29th	ESE & SSE
"	1862	Jan. 15	10	19°0	19th	29°5	21st	SE & ESE
Harrogate	1863	Dec. 31	11	13°5	8th	23°5	7th	SE
Ripon.....	1864	Dec. 23	8	19°2	27th	26°5	25th	SE, E, & SSE
Hawsker, near Whitby	1870	Feb. 8 ¹	8	13°4	12th	29°8	12th	ESE & SE
"	1870	Dec. 21	45	9°0	31st Dec.	25°0	Jan. 1st	E, and then chiefly S
Aysgarth	1880	Jan. 8	23	17°0	19th	28°5	13th	E and SE, then calm and va- riable
"	1887	Jan. 14	6	17°0	17th	29°8	16th	SE & SSE
"	1889	Dec. 27	5	21°8	29th	30°0	28th	ESE & SE
"	1890	Dec. 7	47	12°5 7°9	Dec. 14th Jan. 18th	25°8	13th Dec.	SE

¹ Perhaps a doubtful case.

REMARKS.—Red Hall: 1855, weather generally bright, thawed with South-west wind; 1858, began calm, with hoar frost; 1861, thawed with North wind. Harrogate: 1863, weather generally bright. Hawsker: 1870, much wind and snow on coast, thawed with North-east wind, frost severe on Continent. Aysgarth: 1880, frost most intense when wind East and South-east; 1887, thawed with South-west wind; 1889, ditto.

Looking at the list, then, it seems worthy of remark that the only "South-east Frosts" which lasted more than about 10 days occurred at intervals of about 10 years, namely in 1870-1, in January 1880, and in 1890-1. These lasted 45, 28 and 47 days respectively. They were coincident in time with frost of extreme severity in France and central Europe. As might be expected, there was keener frost in the south-east of England than in the north, and comparatively mild weather prevailed, I believe, in Scotland and in Norway.

But the great frosts of January and February 1855, 1860-1, December 1874, 1878-9, and January 1881 were not "South-east Frosts." I cannot compare the intensity of the two first with last winter's frost, not having observed them in the same locality. But for duration of cold 1878-9 carries off the palm, since the mean temperature of the three months, December, January and February, was as low as 80°·4. For severity nothing approaches to January 1881, when the mean of 21 consecutive days was 21°·6 at Aysgarth, and at stations in the valleys considerably below 20°. Last winter the mean of December was 31°·1, and of January 38°·9.

"South-east Frosts" are more easily distinguished from others in the north of England than in the south, both by the direction of the wind and by absence of snowfall.

In the south-east of England the wind is generally East and not South-east, and sometimes even North-east. In Yorkshire it is generally between East-south-east and South-south-east. In Scotland and Ireland it may blow from South-south-east, South, or South-south-west, but only a native of the "Emerald Isle" could speak of a South-east Frost there, seeing that in such cases they have usually no frost at all. Probably an anticyclone over north Germany or the south of Norway usually occurs when a South-east Frost occurs in Yorkshire, which might account for the curl of the wind on its way north.

Returning, then, to the north of England, I would say that the distinguishing points in "South-east Frosts" are these:—

1. A wind from some quarter between East and South-south-west, but usually between East-south-east and South-south-east.

2. Absence of snow so long as the wind holds in the South-east. This hardly applies to the south of England, where the wind has just crossed the Channel and contracted some moisture. In Yorkshire a fall may occur if a temporary shift of the wind to North-east happens without bringing on a thaw.

3. A small range of temperature with especially low maxima.

4. Rarely a cloudless sky, more generally one that is dull, dry and dirty-looking, the sun having little power, and terrestrial radiation being also weak.

5. If the frost continues the wind generally falls light and fog prevails in the lowlands.

6. A decided shift of the wind to any other quarter brings a tendency to thaw, and especially if it becomes North or North-west.

It seems probable that any very severe frost on the Continent tends to produce a "South-east Frost," provided that there is milder weather over our Islands at the time, and the difference of temperature is therefore large.

It cannot be denied that the surface wind has an unpleasant tendency to blow from wherever the temperature is lowest, to whatever extent this tendency may be over-balanced by the great general movements of the atmosphere, which, however, themselves are of necessity set in motion on a vast scale by the same tendency, which *e.g.* produces the Trade Winds.

Given, therefore, a severe frost on the Continent, a milder temperature over our Islands and an approximate state of equilibrium to the westward of them (the greater movements of the atmosphere thus offering no hindrance), it may be expected that a South-east wind will rise and bring the cold to us. But, of course, it very often happens that some eddy of the great South-west Atlantic wind interferes with the "South-east Frost" within a very few days, or prevents it from coming on at all.

Towards the end of a long frost of any kind, there are often bitter winds from East and South-east, when the frost on the Continent has become very severe. No doubt the conditions are then somewhat similar to those which I have described in the case of "South-east Frosts." But the sky is then as a rule entirely overcast, and it is probable that a "depression" has appeared in the west, and that a change will soon occur.

In considering the frost of last winter as a "South-east Frost," I must explain that I mean the frost which began December 7th, 1890. There was frost (with snow) from November 24th to 30th. That came from the north-east. Intense cold was reported in Lapland, which speedily pushed its way south-westwards. A milder temperature in the north quickly followed in the wake of this cold wave. But in France and Central Europe the wave was arrested and the cold continued. And by December 7th the conditions were favourable for a "South-east Frost" of the kind which I have described. No snow fell here at first, and very little before Christmas. There were few clear nights or days. With its cold, dull, dry and dreary weather, and steady penetrating frost day and night, last December was a joy to skaters but not to everybody.

The brilliant, cloudless, sunny days, which are so pleasant a feature of frosty weather in the Yorkshire dales, were few. Scarcely 29 hours of bright sunshine were registered in the month, of which 24 occurred on 5 days only. A photographic incident will illustrate the dulness of the weather. I exposed a plate at noon in the same spot and on practically the same view which I had taken some years ago during a bright February frost in 6 seconds. This time I gave 12 minutes with the same stop, and the plate was rather under-exposed. There was no snow on the ground on either occasion, nor was there any fog or other non-actinic condition on the latter day. The plate used in December 1890 was about twice as slow, but even allowing for this, the difference is enormous. Sometimes the cloud canopy was very low. On one day, at all events, we were above it.

A peculiarity of the late frost was that an increase of cold occurred in January 1891 with a North wind, and the conditions were then altered. It became much colder in the north, and the sky brightened, and after a fall of snow the frost culminated in very low temperatures on the 18th. In more than one low-lying place near Bedale -8° was observed. But the "South-east Frost" was really over early in January, and had been succeeded by one of ordinary type.

RAIN GAUGES, EVAPORATION GAUGES, ETC.

Twelfth Annual Exhibition of Instruments,

Held, by permission of the Council of the Institution of Civil Engineers, at
25 Great George Street, Westminster, S.W.

MARCH 3RD TO 19TH, 1891.

OLD PATTERN RAIN GAUGES.

12-INCH GAUGES.

1. **Side Tube Rain Gauge.** The water passes into the body of the gauge, and also into the glass tube, and stands at the same level in each. As the combined area of these tubes is very much less than that of the receiving surface, the natural depth of the rain is proportionally increased, and thus the scale is lengthened in proportion—usually about eight or ten times,—so that the quantity can be read off to hundredths of an inch.

Exhibited by Messrs. NEGRETTI AND ZAMBRA.

2. **Contracted Float Gauge.** In this pattern, instead of having a glass tube, which is very liable to breakage, the receiver contains a copper float, to the upper side of which a rod is attached. When rain falls the rod is lifted, and owing to the small area of the body of the gauge as compared with that of the rim, the float rises about eight times the natural depth of the rain—this cannot easily be read nearer than to $\frac{1}{16}$ th of an inch.

Exhibited by Messrs. NEGRETTI AND ZAMBRA.

10-INCH GAUGES.

3. **Old Copper Rain-Gauge,** constructed in 1855 and used at the Kew Observatory till June 1890; square funnel, receiving area 100 sq. ins.

Exhibited by the KEW COMMITTEE.

8-INCH GAUGES.

4. **Glaisher's earliest cylindrical form,** with bevelled rim and curved pipe. The rim round the gauge, about $\frac{3}{4}$ of the way up, was designed to make a water-tight joint, so as to prevent any of the rain inside escaping by evaporation. The same object was aimed at by the curved tube or inverted siphon, in which the last few drops of rain remained and (until they dried up) formed a water-seal.

Exhibited by Messrs. NEGRETTI AND ZAMBRA.

5. **FitzRoy's Rain Gauge.** This is cylindrical in shape with a funnel let into the top; and the rainfall is collected in an inner and much smaller cylinder. The amount of rain is ascertained by a graduated dipping tube which has a hole at each end. This tube is placed upright in the gauge with its upper end open, then the thumb is pressed on the upper aperture while the tube is lifted gently out, holding in the lower part a quantity of water representing the depth of rain in the gauge. The graduations on the tube are fixed by actual trial with an ordinary rain gauge.

Exhibited by THE METEOROLOGICAL COUNCIL.

5-INCH (AND SMALLER) GAUGES.

6. **Howard's Rain Gauge.** Designed by Luke Howard, F.R.S., and engraved in the first edition of his *Climate of London*, published in 1818. The area of the funnel is about eleven times that of the measuring jar, so that minute measurements are possible.
Exhibited by Messrs. NEGRETTI AND ZAMBRA.
7. **Howard's Rain Gauge** with stoneware bottle instead of glass, introduced about 1850 with the view of reducing the frequency of breakage.
Exhibited by L. P. CASELLA, F.R.Met.Soc.
8. **Howard's Rain Gauge** as modified by the late Mr. H. H. Treby of Goodmoor, rough divisions being put upon the bottle so that an approximate idea of the amount of fall might be obtained without the gauge being interfered with.
Exhibited by L. P. CASELLA, F.R.Met.Soc.
9. **Howard's Rain Gauge**, a first modification by Mr. G. J. Symons, being an attempt to protect the glass bottle, and yet allow of inspection as in Mr. Treby's gauge. This gauge, however, had two faults, the bottle did not hold enough, and if it burst, the can being pierced could not save the water.
Exhibited by Messrs. NEGRETTI AND ZAMBRA.
10. **Symons's Rain Gauge.** This was the previous gauge so modified as to remove the above mentioned evils, the bottle was larger and the can watertight.
Exhibited by L. P. CASELLA, F.R.Met.Soc.
11. **5-in. Side Tube Rain Gauge.** *Exhibited by L. P. CASELLA, F.R.Met.Soc.*
12. **Coffee-Pot Rain Gauge**—so called from its shape. This was a very handy gauge, but it had two faults: (1) that it was frequently blown over—this could be cured by suitable hooks; (2) it was the worst possible pattern for frost—this latter fault was incurable.
Exhibited by G. J. SYMONS, F.R.S.
13. **Stevenson's Rain Gauge.** This was an attempt to bring the rim of the gauge to the level of the ground, and yet to avoid insplashing. The inventor advised having a brush made to surround the gauge, but as tried at Strathfield Turgiss a small mat with a hole in it was substituted. Mr. Griffith reported that it was a very difficult gauge to work, and that its chief efficiency was in collecting insects.
Exhibited by G. J. SYMONS, F.R.S.
14. **Fleming's Rain Gauge.** This is a very small float gauge, formerly much used in Scotland, but now nearly abandoned, because when the quantity of rain collected exceeds 2 inches, rain which ought to pass over the gauge is caught by the measuring rod and runs down it into the gauge. It was also usually placed so nearly level with the ground that surface water occasionally entered, and it had other faults.
Exhibited by G. J. SYMONS, F.R.S.

EXPERIMENTAL RAIN GAUGES.

15. From Col. Ward's original magnitude series—the 2 in., 4 in., and 12 in. circular gauges, and the 5 in. and 10 in. square ones. (This last is what used to be known as the Royal Engineer's Rain Gauge.)
16. From Col. Ward's original elevation series—the gauges were all identical—the 10 ft. one only is exhibited.
17. From the series constructed for Mr. Symons to test the effect of various receiving surfaces (tin, copper, glass, porcelain and ebonite), the porcelain one, worked successively at Camden Square, at Framfield, Sussex, and at Strathfield Turgiss is exhibited.
Exhibited by G. J. SYMONS, F.R.S.

NEW PATTERN RAIN GAUGES.

8½-INCH GAUGE.

18. **Rain Gauge 8½ inches in diameter** employed by the Manchester, Sheffield, and Lincolnshire Railway Co. *Exhibited by THE M. S. & L. R. Co.*

8-INCH GAUGES.

19. **Meteorological Office Gauge.** This is generally regarded as the best gauge for ordinary observers to whom cost is not a primary object. It has all the good features of the Glaisher and of the Snowdon patterns, and being of copper is of course very durable.

Exhibited by THE METEOROLOGICAL COUNCIL.

20. **Glaisher's Gauge.** This is the Glaisher pattern, modified by the substitution of a vertical rim (to cut the rain drops) for the original bevelled one on which they would break, and by the substitution of a long straight pipe for the curved one which was found to be frequently choked with leaves, &c.

Exhibited by Messrs. NEGRETTI AND ZAMBRA.

5-INCH GAUGES.

21. **Symons's Snowdon Gauge.** In the autumn of 1864 the late Major Mathew undertook to provide a number of gauges for the district round Snowdon; for that district Mr. Symons provided gauges with cylinders rising 4 inches vertically from the edge of the cone of the funnel—these are called Snowdon rims, and funnels so provided are gradually displacing all others because they are so much better in time of snow. A gauge of this kind in copper is nearly indestructible, and independent of frost, because two vessels (one of glass and one of copper) must burst before the water can be lost.

Exhibited by L. P. CASELLA, F.R.Met.Soc.

22. **Symons's Galvanized Snowdon Gauge.** The special features of this gauge are that while it is accurate, and will last for 15 or 20 years, its cost is very small.

Exhibited by Messrs. NEGRETTI AND ZAMBRA.

MOUNTAIN RAIN GAUGES.

23. **Mountain Gauge.** This is the pattern adopted by Mr. Symons (see *British Rainfall*, 1867, p. 16), for rough mountain work, and for waterworks purposes in wet districts. It is capable of containing 48 inches of rain, and may be read off to tenths of an inch. It is constructed with much care, and all known sources of error (frost, evaporation, insplashing, &c.) are guarded against. The rod is detached from the float (to avoid error from its intercepting the rain), and only dropped into the cup when an observation has to be made. The cross-piece enables the reading to be taken very accurately. The instrument has an outer cylinder to guard against frost and to facilitate emptying.

Exhibited by L. P. CASELLA, F.R.Met.Soc.

[As at the last moment a specimen could not be supplied an engraving was shown instead.]

24. **Engineers' or Waterworks Gauge.** This is identical in principle with the above, but modified to render it suitable for districts of which the mean annual rainfall does not exceed 40 inches. The inner vessel is only 5·658 inches in diameter, while the receiving surface is 8 inches, therefore the float rises two inches for each inch of rain—thus giving an open scale, which can be read to the hundredth of an inch, if desired. It will hold about 12 inches. *Exhibited by L. P. CASELLA, F.R.Met.Soc.*

25. **Symons's Small Mountain Gauge.** This is an attempt to provide a gauge accurate, low in price, frost resisting, holding 20 inches of rain, and easily read by shepherds, miners, and gamekeepers, as it is used chiefly in unfrequented mountain districts where it can be visited at long intervals only.

Exhibited by Messrs. NEGRETTI AND ZAMBRA.

26. **Bradford Waterworks Gauge,** designed by Mr. A. R. Binnie, C.E., for use on the gathering grounds of the Bradford Corporation: it has a Snowdon rim, a large copper pail to hold 17 inches of rain, and the measuring jar holds 1 inch instead of $\frac{1}{4}$ inch as usual.

Exhibited by L. P. CASELLA, F.R.Met.Soc.

27. **Green's Mountain Rain Gauge.** This was designed by Mr. T. Green of Grasmere, for use on the Westmoreland Mountains: one is now at work there at an altitude of 2,860ft., it has two inner cans, so that if one burst the other will save the water, and the funnel is removable so that in winter there is ample room for snow.

Exhibited by Messrs. NEGRETTI AND ZAMBRA.

STORM GAUGES.

These are gauges not intended for general use, or for yielding continuous records, *for which they are not adapted*, but to enable observers to observe the most minute details of heavy rain during thunderstorms. Carefully attended to, they yield information of the very highest importance, both for architects and for engineers, as to the rate at which rain falls. With one of these instruments in London on June 23rd, 1878, rain was ascertained to be falling for 30 seconds at the rate of 12 inches an hour, or 288 inches a day.

28. **Symons's Storm Gauge—First Pattern.** In this a small funnel discharges into a tube, of which the diameter is so small that an inch of rain fills nearly 2 ft.; in the tube is a light ball of opal glass, this rises with the water, and can easily be seen against the black board even 10 or 20 ft. away. When the first tube is full, the overflow passes into a second, in which also there is a float, so that the record can be continued until two inches have fallen. The tubes are closed at the bottom by india-rubber tubes, and on the compress being removed the water escapes, the floats fall to the bottom, and the tubes being re-compressed, the gauge is ready for fresh observations. This gauge is broken if the least frost finds any water in it, and therefore it should be put out only during the summer months. The specimen is divided to show the rainfall on the metric system.

Exhibited by Messrs. NEGRETTI AND ZAMBRA.

29. **Symons's Storm Gauge—Second Pattern.** This is a much stronger and better instrument, but more expensive. The rain passes into a copper cylinder in which is a float, which rises as the rain falls. The float has a string passing round a pulley and kept tight by a counterpoise, therefore when the float rises, the pulley turns; at the extremity of the axle of the pulley there is fixed a hand like the minute hand of a clock, and the size of the parts is so arranged that this hand completes a revolution when 1 inch of rain has fallen. Inside the case there is very simple wheelwork whereby another short hand, like the hour hand of a clock completes a revolution for 5 inches. With this gauge it is therefore quite easy to read from a window the fall of rain to hundredths of an inch, and by doing this, say, every 30 seconds, the minutest detail of the fall of rain can be ascertained. Constructed by Messrs. Negretti and Zambra.

Exhibited by G. J. SYMONS, F.R.S.

REGISTERING AND RECORDING RAIN GAUGES.

30. **Crosley's Registering Rain Gauge.** The area of this gauge is 100 ins., and beneath the tube leading from the funnel, there is a vibrating divided bucket; when one compartment has received a cubic inch of water, *i.e.* 0.01 in. of rain has fallen, the bucket tips, the index advances on the first dial, and the other bucket begins to fill, and so on indefinitely.
Exhibited by Messrs. NEGRETTI AND ZAMBRA.
31. **East India Company's Modified Crosley Rain Gauge.** This differs from the Crosley chiefly in the recording arrangement. In place of the series of cog-wheels moving hands, the tipping bucket moves a weighted lever, which at each movement advances a graduated circle one division, the figures on the circle being read through a small opening in the side of the case. A small dial with a metal hand carries the record up to 100 ins.
Exhibited by G. J. SYMONS, F.R.S.
32. **Yeates's Electrical Self-Registering Rain Gauge.** The funnel is 100 square inches in area, and the measuring bucket (the working parts of which are made of platinum alloy with agate bearings) is adjusted to turn with one cubic inch of water. At each turn of the bucket electrical contact is made, and the index hand moves one division. The advantage of this instrument is that the funnel may be placed in any exposed position out of doors, while the registering part can be fixed indoors.
Exhibited by Messrs. YEATES AND SON.
33. **Stutter's Registering Rain Gauge,** with 24 collecting jars.
Exhibited by the KEW COMMITTEE.
34. **Beckley's Self-Recording Rain Gauge.** (See *Report of the Meteorological Committee*, 1869, p. 36.)
Exhibited by the KEW COMMITTEE.
35. **Casella's Self-Recording Rain Gauge.** The recording portion only, as this instrument is sometimes used in a self-contained iron case standing on the ground, sometimes in a glass case in an observatory, the water being brought down by a pipe from a funnel above. The bucket becomes heavier as rain falls, and when 0.20 in. has fallen it has drawn the pencil from one side of the cylinder to the other, the bucket tips and empties, and the pencil goes back to zero. In this pattern a shutter has been so arranged that any rain falling during the time the bucket is emptying is saved and allowed to pass into the next measurement.
Exhibited by L. P. CASELLA, F.R.Met.Soc.
36. **Richard's Self-Recording Rain Gauge. Float Pattern.** This consists of a funnel for collecting the rain and a pipe leading it into the reservoir in which there is a float. A style, carrying a writing pen, follows the motion of the float, rising 4 in. for a rainfall of 0.4 in. When the pen reaches the top of the revolving drum, the reservoir empties itself, the float falls to the bottom, and the pen returns to zero. The emptying of the reservoir is automatically obtained by a siphon, the starting of which is secured by an electro-magnet which, on the circuit of a battery being completed, pulls the float down and causes a sudden rise of the water-level, thereby filling up the siphon.
Exhibited by MM. RICHARD FRÈRES.
37. **Richard's Self-Recording Rain Gauge. Balance Pattern.** This consists of a funnel and pipe leading the rain into a tipping bucket divided into two compartments and placed on a balance. One of these compartments being under the funnel, the rain falls into it and causes the balance to descend; a writing pen records this motion on the revolving drum. When the pen has reached the top (0.4 in. of rain) the tipping bucket reservoir oscillates, and the water filling the first compartment is emptied into a controlling reservoir. This motion causes the second or empty compartment of the bucket to place itself under the funnel. The filling and emptying of each compartment is alternately and automatically produced, and to each of these double operations corresponds a rise and a fall of the writing pen. *Exhibited by MM. RICHARD FRÈRES.*

FOREIGN RAIN GAUGES.

38. **French Rain Gauges.**—Rain gauge as supplied by the *Association Française pour l'Avancement de Science*. *Exhibited by M. le Prof. MASCART.*
- 39.——Side tube Rain gauge. During snow a night light or small lamp is placed upon the upper shelf to melt the snow and prevent the melted water from freezing and bursting the tube.
Exhibited by M. le Prof. MASCART.
40. **Hervé-Mangon's Pluviomètre totaliseur.** The daily fall is read from the side tube, and then the water is passed into the large receiver, and the total is re-measured at the end of the month as a check on the daily readings.
Exhibited by M. le Prof. MASCART.
- 41.——Ordinary gauge with receiver holding two inches of rain, to be drawn off by the tap at its base.
Exhibited by M. le Prof. MASCART.
42. **Hellmann's Rain and Snow Gauge.** First pattern devised in 1883. The receiver and collector are combined, the latter having a stop cock. There are two vessels for changing the one for the other in winter when snow is falling. This pattern is now abandoned in Prussia, but is used in Alsace-Lorraine.
Exhibited by Dr. G. HELLMANN.
43. **Hellmann's Rain and Snow Gauge.** Second pattern devised in 1886, and now used in the Prussian Meteorological Service.
Exhibited by Dr. G. HELLMANN.
44. **Hellmann's Gauge for measuring the density of Snow.**
Exhibited by Dr. G. HELLMANN.
45. **Wild's Rain Gauge, as used in Russia.** This consists of two cylindrical zinc vessels. The upper receiver is fitted with a brass rim to prevent possible loss by splashing. The water passes from the upper receiver through a kind of sieve into the lower vessel, and any air forced in with it escapes through the lateral turned up tube. The water in the lower vessel is let into a graduated glass by the tap.
Exhibited by the METEOROLOGICAL COUNCIL.
46. **Colladon's Instrument for determining the Temperature of Hail.**
Exhibited by Dr. W. MARCET, F.R.S.
47. **Nipher's Protected Snow Gauge.** (See *Report of the Chief Signal Officer, U.S.A., 1887, part 2., p. 384.*)
Exhibited by the KEW COMMITTEE.

MISCELLANEOUS RAIN GAUGES.

48. **4½-in. Tropical Rain Gauge.** The receiver of this gauge is large enough to hold 40 ins. of rain.
Exhibited by L. P. CASELLA, F.R.Met.Soc.
49. **Livingston's Rain Gauge.** This is a 3 in. copper gauge with upright rim, copper receiver, and glass measure, as made for the late Dr. Livingston.
Exhibited by L. P. CASELLA, F.R.Met.Soc.
50. **Marine Rain Gauge.** Mounted on gimbals for use on board ship.
Exhibited by THE METEOROLOGICAL COUNCIL.
51. **Snow Melting Rain Gauge.** Invented by, and constructed for, Mr. James Sidebottom, F.R.Met.Soc. The case is double, warm water is poured into the angular tube, and when the snow (with which it is never in contact) in the funnel is melted the water is run off by the tap, and, if needed, a fresh supply is added. By this arrangement any mistake from adding a wrong quantity of water is impossible.
Exhibited by J. SIDEBOTTOM, F.R.Met.Soc.
52. **Snow Gauge.**
Exhibited by E. MAWLEY, F.R.Met.Soc.

EVAPORATION GAUGES.

53. **Babington's Atmometer.** This consists of an oblong hollow bulb of glass or copper, beneath which, and communicating with it by a contracted neck, is a second globular bulb, duly weighted with mercury or shot. The upper bulb is surmounted by a small glass or metal stem, having a scale graduated to grains and half-grains, on the top of which is fixed a shallow metal pan. The bulbs are immersed in a vessel of water having a circular hole in the cover through which the stem rises. Distilled water is poured into the pan above until the zero of the stem sinks to a level with the cover of the vessel. As the water in the pan evaporates, the stem ascends and the amount of the evaporation is indicated in grains.

Exhibited by L. P. CASELLA, F.R.Met.Soc.

54. **von Lamont's Atmometer.** The evaporation pan is a shallow cylinder with a slightly curved bottom, from the middle of which a narrow pipe leads to a vertical cylindrical reservoir of water containing a closely fitting piston. The position of this piston in the cylinder is adjustable by means of a screw which moves the piston vertically, and it can be read by a vertical scale attached to the piston, a pointer being attached to the cylinder. The method of observing is as follows:—The piston is screwed up so as to allow the water in the evaporation pan to run into the reservoir, leaving the connecting tube just full, so that the water just makes the curved surface of the bottom of the pan continuous; the scale is then read and the water driven by the piston up to within a little of the top of the pan, and the evaporation allowed to take place, the piston is then raised so that the water sinks again from the pan to the same point as before, and the scale is read again. The difference of readings in scale divisions gives the depth of water evaporated.

Exhibited by THE METEOROLOGICAL COUNCIL.

55. **Wild's Evaporimeter.** Evaporation takes place from a free surface of water, in a shallow cylindrical dish supported on the short arm of a lever balance. The longer arm, acting as a counterpoise, is provided with a pointer which moves over a graduated quadrantal arc, and the loss of weight, due to the evaporation of water from the dish, is indicated by the change in the position of the pointer on the scale. The diameter of the dish is 178 mm. (7 inches.)

Exhibited by THE METEOROLOGICAL COUNCIL.

56. **de la Rue's Evaporimeter.** In this the water evaporates from a surface of moistened parchment paper, stretched over a shallow drum kept full of water, which is supplied from a cylindrical reservoir giving about 6 ins. head. Into this vessel dips a narrow metal tube forming the only opening into a graduated cylinder of glass about 6 ins. high and $1\frac{1}{2}$ in. diameter. The glass cylinder is originally filled with water, and the tube leading from it, which dips into the reservoir, is perforated laterally. The water in the reservoir is therefore maintained at a constant level by a flow of water from the glass cylinder whenever the lateral opening becomes exposed to the air. The amount of water evaporated is given by the graduations on the glass cylinder, which are so drawn as to express the evaporation in hundredths of an inch.

Exhibited by THE METEOROLOGICAL COUNCIL.

57. **Piche's Evaporimeter.**—This consists simply of a graduated cylindrical tube of glass closed at one end, and having the open end ground flat and covered by a disc of blotting paper about three times the diameter of the tube. This is kept in its place by a disc of the same diameter of the tube and attached to it by a spring. The instrument is hung vertically with the closed end upwards, so that as the water evaporates from the wet paper very small bubbles of air rise in succession to supply its place in the tube. The amount evaporated can be inferred from the scale engraved on the glass tube.

Exhibited by the METEOROLOGICAL COUNCIL.

58. **Richard's Self-Recording Evaporation Gauge.** This consists of a pair of scales, one of which bears a basin of water or a plant. Weights are placed in the opposite scale to establish a state of equilibrium. A style is attached to the scale beam, and the pen records its motions on a revolving drum. The sensitiveness of the scale is regulated by a sliding weight, which being raised or lowered, raises or lowers the centre of gravity of the scale beam.
Exhibited by MM. RICHARD FRÈRES.

59. **Evaporimeter, designed for use with growing Plants in a Botanical Laboratory.** A steel tape passes over a pulley resting on knife edges and supports the plant at one end and a counter-weight at the other. The pulley turns as the plant becomes lighter, moving a cup of mercury away from the mouth of a tube, and allowing the air to escape from the gas bag. The board resting on the bag falls and moves the pen; it also increases the tension of a spring acting on the pulley; this continues till the balance is restored and the mouth of the tube is again closed. The ordinates of the curve drawn are proportional to the change of weight. If the change of weight varies from negative to positive, a connection is made to the gas main to give a small continuous supply to the gas bag, or a simple arrangement in connection with the water main is used.
Exhibited by THE CAMBRIDGE SCIENTIFIC INSTRUMENT CO.

60. **Apparatus used by the late Mr. G. Dines for measuring Evaporation.** A float is fixed on a centre at the bottom of the smaller vessel; as the water in the larger vessel is lowered by evaporation, the float falls over and the quantity is measured upon the circular arc. The large vessel was immersed in water in a slate tank to within an inch of its rim.
Exhibited by W. H. DINES, B.A., F.R.Met.Soc.

61. **Floating Rain Gauge and Evaporating Cup for ponds.** The instrument consists of a wooden float block, having two cavities in it holding a rain gauge and an atmometer, each removable at pleasure. The cavities communicate with the water underneath, in order to keep the gauges of the same temperature throughout. The evaporator has a louvre over it to keep out the sun's rays, but admits the wind through it. The rain gauge has a perforated diaphragm to keep out the sun's rays, and to prevent evaporation of the contents. The apparatus is intended to be floated out and moored in the centre of a piece of open water, and left there as long as suited to the state of the weather, and then drawn back again to shore. The gauges are then to be examined, and the quantities of water remaining ascertained by measuring glasses in the usual way.
Exhibited by Surgeon-Major W. G. BLACK, F.R.Met.Soc.

62. **From the series of Evaporators constructed under the supervision of Mr. Rogers Field, C.E., and described in *British Rainfall* in 1889:—**

- (1) The Fletcher evaporator, as arranged by the late Mr. Isaac Fletcher, M.P., F.R.S.
- (2) The Watson evaporator, as designed by Dr. Dalton, F.R.S., and worked for nearly half-a-century by the late Mr. H. H. Watson, F.C.S.
- (3) Miller's Wet sand evaporator.
- (4) Tin evaporator.
- (5) " " with overflow.
- (6) Casella's Can.
- (7) " " Bottle.
- (8) Hook gauge, used for determining depth evaporated from the large tank, 6 ft. square and 2 ft. deep, which was used as the standard wherewith the foregoing and some other forms of instrument were compared.

Exhibited by G. J. SYMONS, F.R.S.

63. **Casella's 8 in. Pedestal Evaporator.**

Exhibited by L. P. CASELLA, F.R.Met.Soc.

INSTRUMENTS NOT PREVIOUSLY EXHIBITED.

64. **Self-Recording Apparatus for Wells, Rivers, Reservoirs, &c.** The action of the apparatus is briefly as follows :—A card which is fixed on a vertical drum is caused to rotate by clockwork, and a float on the surface of the water communicates its motion through a rack and pinion to a pencil, which thus shows, on a reduced scale, the variation in the level of the water. Besides its application as a tide-recording instrument, the apparatus can be used in conjunction with an overflow weir or notch for the purpose of gauging the flow of streams, in which case the diagram shows the depth of water flowing over the weir. It can also be applied to the fluctuation of water level in a well, and the yield of the well, to show whether that is influenced by pumping, and it can be made to furnish data for calculating the yield of a well which has been pumped down, by automatically recording the rate at which the well refills. The weight of the float and cord is counterpoised by a spring, and the vertical scale of the diagram can be varied at pleasure.

Exhibited by BALDWIN LATHAM, Pres.R.Met.Soc.

65. **Helicoid Anemometer**, with helicoid fan 24 ins. by 5 ins., fitted with Dines' and Munro's patent arrangement for indicating at sight on a dial the velocity and pressure of the wind; also mechanism to register up to 9,999 miles, and tenths and hundredths of miles.

Exhibited by R. W. MUNRO, F.R.Met.Soc.

66. **Robinson's Anemometer** with cups 5 inches diameter, fitted with Dines' and Munro's patent arrangement for indicating by a scale on a vertical glass tube the velocity and pressure of the wind.

Exhibited by R. W. MUNRO, F.R.Met.Soc.

67. **Helicoid Air Meter**, with 6 inch helicoid fan, registering up to 100,000 feet.

Exhibited by R. W. MUNRO, F.R.Met.Soc.

68. **Statoscope.** This is a very sensitive atmospheric barometer. The writing pen has a 13 millimetre ($\frac{1}{2}$ inch) stroke for each millimetre variation in the mercurial column.

Exhibited by MM. RICHARD FRÈRES.

69. **Anemo-Cinémograph.** This instrument indicates and registers the velocity of the wind in miles per hour, directly and without any calculation.

Exhibited by MM. RICHARD FRÈRES.

70. **Self-Recording Aneroid Barometer**, going for a week and marking a dot on the paper every 15 minutes.

Exhibited by Mons. G. MEYER.

71. **Instrument for rendering apparent and measureable momentary oscillations of Atmospheric Pressure.**

Exhibited by A. E. BENNETT.

72. **Early Pattern of Solar Radiation Thermometer in vacuo** with black glass bulb and certificate.

Exhibited by F. C. BAYARD, LL.M., F.R.Met.Soc.

73. **Small Camera for Meteorological Photography**, showing a simple method of attaching a mirror of black glass for photographing meteorological phenomena.

Exhibited by A. W. CLAYDEN, M.A., F.R.Met.Soc.

74. **Larger Camera for Photographing Clouds and Lightning.** The black mirror is finely-ground glass, blackened on the rough side. This apparatus is attached to a simply constructed stand, which can be clamped to a window-sill.

Exhibited by A. W. CLAYDEN, M.A., F.R.Met.Soc.

75. **Frame for Measuring Cloud Pictures** for determining height and drift of clouds, designed by Gen. R. Strachey, F.R.S., and Mr. G. M. Whipple, F.R.A.S.

Exhibited by the KEW COMMITTEE.

PHOTOGRAPHS, &c.

76. **New York Blizzard of March 12-14, 1889.** Three Views.
Exhibited by H. P. CURTIS.
77. **Self-Recording Rain Gauge** used at the Ufficio Centrale di Meteorologia, Rome.
Exhibited by Prof. P. TACCHINI.
78. **Flood at Rotherham Railway Station, May 15, 1886.** Two Views.
Exhibited by E. M. EATON, F.R.Met.Soc.
79. **Flood on the Severn at Worcester, May 15, 1886.** Two Views.
Exhibited by G. B. WETHERALL, F.R.Met.Soc.
80. **Rain Gauge Experiments.** Photographs illustrative of Calne series.
First site of the experiments originated by Col Ward, F.R. Met. Soc., to determine (1) the effects of placing gauges at different heights above the ground, not (as had been done previously) on buildings, but on posts, and (2) to ascertain whether there is any difference in the indications of gauges ranging in diameter from 1 to 24 inches, and including square ones of 25 and 100 inches area. This photo shows the gauges as placed at Castle House, Calne, Wilts.
Exhibited by G. J. SYMONS, F.R.S.
- 81.——The same gauges removed to Strathfield Turgiss, Hants, in order to ascertain what effect, if any, local influences had in producing the results noticed at Calne.
Exhibited by G. J. SYMONS, F.R.S.
82. **Rotherham Experimental Gauges.**—General view of the apparatus erected by Mr. Chrimes on the cover of Boston Reservoir, Rotherham, in order to study the diminution in the amount collected by gauges elevated above the ground, and its probable cause.
Exhibited by G. J. SYMONS, F.R.S.
- 83.——Weighing-machine used to ensure precision in the measurements in the preceding experiments. The beam turned readily with 0.001 in. It is shown with, and without, one of the collecting vessels.
Exhibited by G. J. SYMONS, F.R.S.
- 84.——Five mouthed gauge, part of the Rotherham series; it has one horizontal mouth and four vertical ones facing N.E.S. and W. respectively. From its records the altitude and azimuth whence any fall of rain comes can be computed.
Exhibited by G. J. SYMONS, F.R.S.
- 85.——Forty-five degree gauge—of the same series—two views. In this gauge the funnel was set at an angle of 45°, and it was attached to a powerful vane which kept the orifice always in the azimuth of the prevailing wind.
Exhibited by G. J. SYMONS, F.R.S.
- 86.——Tipping gauge of same series—two views. In this case the funnel was not only kept in the azimuth of the prevailing wind, but it was also by the lateral fans so tipped as also to meet its angle in altitude.
Exhibited by G. J. SYMONS, F.R.S.
- 87.——Three views of the same gauges as re-erected on the bank of Ulley Reservoir, Rotherham, in order to compare results with those in their former position.
Exhibited by G. J. SYMONS, F.R.S.
88. **Chester Lead Works.**—Shot Tower of Lead Works, Chester, 160ft. high, used as one (of many) stations for determining decrease of rainfall with elevation above the ground.
Exhibited by G. J. SYMONS, F.R.S.
89. **Boston Church, Lincolnshire,** the tower of which is 273ft. high. Observations have been made on this tower for determining the decrease of rainfall and of temperature with elevation above the ground. (Two views.)
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.
90. **Latham's Self-Recording Rain Gauge.** The rainfall accumulating in the gauge (by means of a float) actuates a pencil on the diagram on a vertical

drum which is driven continuously by clockwork. The record thus obtained shows not only the total amount of rain which has fallen in a given time, but the rate at which it falls. (Three views.)

Exhibited by BALDWIN LATHAM, Pres. R.Met.Soc.

Floods, damage by—

91. ———Two photos of Todmorden flood, July 1870.
92. ———Hereford Railway Station in the flood of 1875.
93. ———Valley House, Chepstow, showing lawn nearly covered with stones washed down from above.
94. ———Sheet of views of Chelmsford flood, August 2nd, 1888.
95. ———Three views of Bristol floods, March 1889.

Exhibited by G. J. SYMONS, F.R.S.

96. **Sites of Rain Gauges in the Lake District.** *Cumberland*—(1) Sty Head Tarn ; (2) Sty Head Pass ; (3) The Borrowdale valley looking south ; the Sty (probably the wettest spot in the British Isles) is near the centre of the photo, and Seathwaite hamlet is just behind the trees further to the west ; (4) Watendlath Tarn ; (5) Grange at the foot of Derwentwater—summer, looking south ; winter, looking south-west ; (6) Buttermere, the gauge is at Hassness near the edge of the lake ; (7) General view of Derwentwater with Keswick in the foreground.

Exhibited by G. J. SYMONS, F.R.S.

97. **Ben Nevis Observatory**—(1) A clear day ; (2) too much hoar frost for the anemometer.

Exhibited by G. J. SYMONS, F.R.S.

98. **Specimens of Cloud Photographs** taken on ordinary Ilford plates by reflection from black mirrors.

Exhibited by A. W. CLAYDEN, M.A., F.R.Met.Soc.

99. **Photographs of Clouds** taken at the Santis Observatory, Switzerland, in 1890.

Exhibited by Prof. A. RIGGENBACH.

100. **Photograph of the Tower of the Winds, Athens.**

Exhibited by Dr. C. T. WILLIAMS, M.A., F.R.Met.Soc.

101. **Models of Hail-Stones**, 7ins. in circumference, which fell near Montereau, France, on August 15th, 1888. (See *Quarterly Journal of the Royal Meteorological Society*. Vol. XV. p. 47.)

Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

MAPS AND DIAGRAMS.

102. **Map of Rainfall of part of Great Britain** prepared by the late Mr. J. Atkinson, of Carlisle, and issued March 1840. (Believed to be the first map of any part of the British Isles showing the Rainfall.)

Exhibited by G. J. SYMONS, F.R.S.

103. **Map of Rainfall over the British Isles**, prepared by the late Mr. Keith Johnston.

Exhibited by G. J. SYMONS, F.R.S.

104. **Map of Rainfall over the British Isles**, based on the average 1860-65, prepared for the *Sixth Report of the Rivers Pollution Commissioners*, by Mr. G. J. Symons.

Exhibited by G. J. SYMONS, F.R.S.

105. **Map showing the Stations** from which a record of the fall of rain in the British Isles was quoted in *British Rainfall* 1889.

Exhibited by G. J. SYMONS, F.R.S.

106. **Map showing the sites of the Rain Gauges** on the Manchester, Sheffield, and Lincolnshire Railway.

Exhibited by THE M. S. & L. R. Co.

107. **Statement of Rain** fallen in the year 1890, at the Stations of the Manchester, Sheffield, and Lincolnshire Railway.
Exhibited by THE M. S. & L. R. Co.
108. **Map of Rainfall of Europe**, prepared by Prof. Otto Krummell.
Exhibited by G. J. SYMONS, F.R.S.
109. **Map of Rainfall of France**, prepared by M. Angot.
Exhibited by G. J. SYMONS, F.R.S.
110. **Rainfall Atlas of Russia**, prepared by Dr. Wild.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.
111. **Map of Rainfall of India**, prepared under the direction of Mr. H. F. Blandford, F.R.S.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.
112. **Map of Rainfall over the S.E. of Australia and Tasmania** during 1884, published by the proprietors of *The Australasian*.
Exhibited by G. J. SYMONS, F.R.S.
113. **Map of Rainfall of South Australia** in 1887, by Mr. C. Todd, F.R.S.
Exhibited by G. J. SYMONS, F.R.S.
114. **Rainfall Map of New South Wales** for 1889, by Mr. H. C. Russell, B.A., F.R.S.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.
115. **Rainfall Chart of the United States**. By Mr. C. A. Schott.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.
116. **Map of Mean Annual Rainfall of the Globe**, by Prof. E. Loomis.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.
117. **Record from Osler's Anemometer** at the Royal Observatory, Greenwich, showing Rainfall for July 4-5, 1890, and corresponding Photographic Record from Thomson's Electrometer.
Exhibited by W. H. M. CHRISTIE, F.R.S., Astronomer Royal.
118. **Diagrams of Barometer, Thermometer, Rain, and Wind**, at Barrow, 1876-9, Kenilworth, 1880-8, and Beckford near Tewkesbury, 1884-90.
Exhibited by F. SLADE, F.R.Met.Soc.
119. **Sheet and Album of Engravings of Self-Recording Rain-Gauges**.
Exhibited by G. J. SYMONS, F.R.S.
120. **Waterspouts**. Early lithograph of "Phénomène de Trombes Marines observé dans la mer de Sicile en vue de Stromboli le 27 Juin, 1827, et dessiné par L. Mazzara à bord du Brigantin le Portia, Captain Cabbage, au moment où le navire fait feu sur la trombe qui le menaçait le plus près."
Exhibited by G. J. SYMONS, F.R.S.
121. **Rothamsted Rain Gauges**.—Coloured Drawing, by Lady Lawes, of the Rothamsted Rain-gauges. For the purposes of accurate measurement of the rain, and of obtaining sufficient quantities for analysis, a large gauge of one-thousandth of an acre area has been in use since the beginning of 1858; also an ordinary funnel-gauge of 5 ins. diameter; and these are represented in the drawing. An 8 inch "Board of Trade" copper-gauge has also been in use since January, 1881. The funnel portion of the large gauge is constructed of wood, lined with lead; the upper edge consisting of a vertical rim of plate glass bevelled outwards. The rain is conducted by a tube into a galvanised iron cylinder underneath, and when this is full it overflows into a second cylinder, and so on into a third and fourth, and finally into an iron tank. Each of the four cylinders holds rain corresponding to half-an-inch of depth, and the tank an amount equal to 2 inches. Each cylinder has a gauge-tube attached, graduated to read to .002 in., but which can be read to .001 in. Small quantities are transferred to a smaller cylinder with a gauge-tube graduated to .001, or one-thousandth of an inch.
Exhibited by Sir J. B. LAWES, Bart., and J. H. GILBERT, LL.D., F.R.S.

122. **Rothamsted Drain (or Percolation) Gauges.**—Coloured drawing by Lady Lawes of the Rothamsted Drain-gauges. The three "Drain-gauges," each one-thousandth of an acre area, for the determination of the quantity and the composition of the water percolating respectively through 20 inches, 40 inches, and 60 inches depth of soil (with the sub-soil in its natural state of consolidation), have been in use since September, 1870,—that is for a period of more than 20 years. The gauges were constructed by digging a deep trench along the front, gradually undermining at the depth required, and putting in plates of cast iron (with perforated holes) to support the mass. The plates were then kept in place by iron girders, and the ends of the plates and of the girders supported by brickwork on three sides. Trenches were then dug round the block of soil bit by bit, and it was gradually enclosed on each side by walls of brick laid in cement. Below the perforated iron bottom a zinc funnel of the same area as the soil was finally fixed, and the drainage water is collected and measured in galvanised iron cylinders with gauge tubes, as in the case of the rain.

Exhibited by Sir J. B. LAWES, Bart., and J. H. GILBERT, LL.D., F.R.S.

123. **Table of Rainfall and Drainage at Rothamsted** for the 20 harvest years ending August 31st, 1890.

Exhibited by Sir J. B. LAWES, Bart., and J. H. GILBERT, LL.D., F.R.S.

124. **Rothamsted Rain Gauges.**—Cylinders of the 1000 acre rain gauge, with side tube attached, reading to .002inch.

Exhibited by Sir J. B. LAWES, Bart., and J. H. GILBERT, LL.D., F.R.S.

G. J. SYMONS, F.R.S.

JOHN W. TRIPE, M.D. } *Secretaries.*

WILLIAM MARRIOTT, *Assistant Secretary.*

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

MARCH 18th, 1891.

Ordinary Meeting.

C. THEODORE WILLIAMS, M.A., M.D., Vice-President, in the Chair.

HORATIO BREVITT, The Leasowes, Tettenhall Road, Wolverhampton ;

JOHN LOVEL, York Road, Driffild ; and

LYALL GEORGE OLIVER, M.A., B. Sc., Grammar School, Newark,
were balloted for and duly elected Fellows of the Society.

Mr. SCOTT stated that the subscriptions promised towards the New Premises Fund amounted to £1,141 8s., and that the Council had taken three rooms on the second-floor at 22 Great George Street, to which the Library and Office would shortly be removed.

The following Paper was read :—

"A CONTRIBUTION TO THE HISTORY OF RAIN GAUGES." By G. J. SYMONS, F.R.S. (p. 127.)

Mr. A. W. CLAYDEN, M.A., F.R.Met.Soc., exhibited (by means of a lantern) a large number of slides illustrating Meteorological Phenomena (p. 142.)

On the motion of Mr. SILVER, seconded by Mr. LECKY, the thanks of the Society were given to the Exhibitors for the loan of their Instruments, &c.

The Meeting was then adjourned in order to afford the Fellows an opportunity of inspecting the Exhibition of Rain Gauges, Evaporation Gauges, &c., which had been arranged in the rooms of the Institution of Civil Engineers (p. 180).

APRIL 15th, 1891.

Ordinary Meeting.

ARTHUR BREWIN, Vice-President, in the Chair.

JOSEPH BAXENDELL, The Observatory, Birkdale, Southport;
HENRY CHAMP, Manchester; and
SAMUEL HARTSHORNE RIDGE, B.A., F.R.G.S., 275 Victoria Parade East,
Melbourne,
were balloted for and duly elected Fellows of the Society.

The following Papers were read :—

"ON THE VARIATIONS OF THE RAINFALL AT CHERRA POONJEE IN THE KHASI HILLS, ASSAM." By HENRY F. BLANFORD, F.R.S. (p. 146.)

"SOME REMARKABLE FEATURES IN THE WINTER OF 1890-91." By FREDERICK J. BRODIE, F.R.Met.Soc. (p. 155.)

"THE RAINFALL OF FEBRUARY 1891." By H. SOWERBY WALLIS, F.R.Met.Soc. (p. 167.)

"SOUTH-EAST FROSTS, WITH SPECIAL REFERENCE TO THE FROST OF 1890-91." By the Rev. FENWICK W. STOW, M.A., F.R.Met.Soc. (p. 176.)

"SNOWSTORM OF MARCH 9TH AND 10TH, 1891, AT SHIRENEWTON HALL, CHEPSTOW." By E. J. LOWE, F.R.S. (See below.)

CORRESPONDENCE AND NOTES.

GREAT SNOWSTORM, MARCH 9TH AND 10TH, 1891, AT SHIRENEWTON HALL, NEAR CHEPSTOW. By E. J. LOWE, F.R.S., F.R.Met.Soc.

THE late snowstorm and gale in this neighbourhood was a marked example of blizzard. There were series of limited areas where a large amount of snow collected, and this snow for the most part had previously fallen, and was again blown from the fields, moving along near the ground until meeting with an obstruction, and then becoming mingled with the snow already gathered there, causing a dense cloud of snow-dust, the snow being broken up into such minute fragments that it more nearly resembled flour than snow.

Driving from Chepstow on Tuesday the 10th, at 4 p.m., I had the opportunity of a close examination. My carriage became firmly embedded in a deep snow drift (varying from 6 to 8 ft. high) before being aware that there was an impenetrable mass of snow close by. A drift could be seen extending half across the road, but at a few yards further on, the blowing snow became so dense that objects at more than the distance of two or three feet were invisible. This snow-dust was forced into, and penetrated, clothes, covering them as if with flour instead of snow, and it could not be shaken off like ordinary snow. It was impossible to face the blizzard, the head had to be turned away from the direction in which the gale was blowing. As there was a narrow open space close to the

opposite hedge, I walked through the whole length (about 50 yards), and at either end the prospect was clear enough to see a distance of two or three miles, even when quite close to the blizzard, the boundaries being so sharply defined.

There were many such drifts in this neighbourhood varying from 80 to more than 100 yards, and the snow in them was so solidly pressed down that, when cut through, the spadesfull thrown out did not fall to pieces. Nearly every place was snowed up for several days, and it was only possible to force a passage on foot after the gale had ceased, for during its continuance it was extremely dangerous to make the attempt. At the worst part of the gale very little snow was actually falling, but the air was full of snow-dust blown from exposed situations until no snow remained in the fields except along the hedges, and where the gale passed across ploughed fields the drifts were much discoloured owing to the large amount of soil that was blown from the fields with the snow.

Roofs of houses facing the gale (*i.e.* North-east) had the snow blown under the slates until in some houses it was 8 ins. deep.

Within the blizzard the cold was intense, apparently much more so than on either side without these drifts.

The clouds of snow moved close to the ground, and, as it were, boiled over the obstructions, at the same time stirring up the snow that had been previously deposited.

It has been very difficult to ascertain what amount of snow fell, as most of it was shifted by the gale. It could only be done in sheltered situations where trees were on the north-east side, and even only approximately with these precautions. The depth of the snow was measured along a line 28 yards in length, situated to the south-west of a plantation of trees and commencing 20 yards from the trees; at the end of this line nearest to the trees was drift snow, and at the other extreme a portion had been blown away.

North-East.	
Measured on Thursday.	Measured on Tuesday Afternoon.
4½ inches	14 inches deep.
3½ "	12 "
3 "	10 "
2½ "	8 "
	.....A.
2½ "	7 inches deep.
1½ "	5½ "
1½ "	4½ "
1 "	3 "
South-West.	

At the point A the depth at 7 a.m. on the 10th was 6 ins., and this was increased in the afternoon to 7½ ins. From near this place the snow was gathered on Thursday at 6 p.m. and melted, it having at that time sunk to 2½ ins., and though the surface had somewhat melted, the water had not passed through the snow. The actual amount when melted was 0.672 in.

To show the difficulty, the ordinary 8 in. rain gauge only caught 0.004 in., a snow gauge 0.120 in., and a second one 0.122 in., whilst a third at 7 a.m. on the 10th (after 6 ins. of snow had fallen, *i.e.* 0.504 of an inch) was placed at an angle of 45° towards north-east, and this collected 1.075 ins., whilst not more than 0.168 in. could have fallen; ¾th being due to blown snow. Hollows in the ground were filled up with the driving snow so that a sunken gauge with the top level with the ground would have been quite full of snow-dust.

At Ilton Court	melted snow	0.950 in.	depth	8 ins.
„ Piercefield Park	„	0.400 "	„	4 "
„ Dannel Hill	„	0.840 "	„	4½ "

The above are all to north-east, and situated 1, 8 and 4 miles distant.

Snow commenced falling at 4 p.m. on the 9th, with a North-east gale, and ceased at 6 p.m. on the 10th, when the gale was over, and it became frosty.

The barometer had been falling from the 4th, but began to rise again at 2 a.m.

TEMPERATURE.

March.	Read at 9 a.m.		Read at 6 p.m.			Mean Temp.	Rain.
	Min. 4 ft.	Min. on Grass.	Max. in Shade 4 ft.	Max. in Sunshine 4 ft.	Max. Sun Vacuum Therm.		
8	34.3	36.1	40.3	41.0	46.0	35.7	In. .403
9	29.5	26.9	36.6	43.0	48.0	31.0	.007
10	25.0	26.8	39.0	40.0	40.0	29.2	.372
11	23.0	25.0	43.1	59.0	72.8	31.5	.300
12	21.5	19.0	42.3	59.0	67.0	31.1	..
13	30.4	28.9	43.4	53.3	67.0	34.4	..
14	30.9	32.1	37.8	38.5	43.1	33.1	.005
15	26.2	22.0	44.8	55.3	71.9	35.0	.634
16	33.1	29.3	46.4	55.8	82.7	36.7	.097

on the 9th, falling again in the afternoon. The wind, which had been South-west and West-south-west, became North on the morning of the 8th, and North-east on the morning of the 9th, South-south-west on the 15th, with much snow from 1.15 p.m. till 8 p.m., and heavy rain after 9 p.m. The wind on the 16th became South-east.

Barometer (corrected and reduced to sea-level).

		Ins.
6th.	2 a.m.	80.201
7th.	2 "	29.818
8th.	2 "	29.687
9th.	2 "	29.770
10th.	2 "	29.488
9th fell gently till 9 p.m.		

From 9 p.m. to 10 p.m. fell .05
 10th, from 2 a.m. till 8 a.m. fell .08
 8 " 4 " .04
 Then very steady till 10 a.m.

From 10 a.m. till 11 a.m., fell .10
 " 11 " noon " .08
 " noon " 1 p.m. " .01
 " 1 " 2 " " .01
 " 2 " 8 " " .01
 " 8 " 4 " " .01
 " 4 " 5 " " .01

And then almost stationary till midnight.

It ought to be explained that the prospect was visible for several miles, owing to the situation being higher than the surrounding country. There were numerous drifts, but they were at a lower level and could be looked over. All roads lower than the surrounding fields were filled up with snow.

SOLAR HALO SEEN AT COOPER'S HILL, STAINES, ON JUNE 9th, 1891. By Prof. HERBERT McLEOD, F.R.S.

A SOLAR halo of an unusual form was observed here on Tuesday, June 9th. At about 9.15 a.m. an elliptical arch was seen over the sun, the highest portions of the arch being brightly coloured, and the sides white and only just visible at about the level of the sun; nothing was seen below the sun. Having to lecture on that morning, I asked Mr. Appleyard, Professor Stocker's Assistant, to measure the halo with a sextant, and at 10.20 a.m. he observed a small portion of the halo

below the sun, but which lasted only a short time. The measurements from the sun to the halo above and below were $21^{\circ}46'$, making the minor axis $43^{\circ}32'$. The measurements from the sun to the halo horizontally were $28^{\circ}15'$, or the major axis subtended $56^{\circ}30'$. The halo afterwards appeared to become more circular, but clouds prevented measurements being taken.

TEMPERATURE AND AREA. Note by E. G. ALDRIDGE, F.R.Met.Soc., F.G.S.

IT is the invariable practice of meteorologists, in calculating the mean temperature of the British Islands from the mean temperatures of the three constituent kingdoms, to assume for these kingdoms equal areas, or rather to overlook the important fact that these three great divisions are not of equal size. Thus, taking Great Britain alone, if the mean temperature of any given period be 50° in England and 40° in Scotland, the mean temperature for the entire island would not be 45° , but about $46\frac{1}{2}^{\circ}$.

THE DESTRUCTIVENESS OF TORNADOES.

At the request of the Chief Signal Officer, Prof. H. A. Hazen has made an inquiry into the average number of Tornadoes in the United States, the area devastated by them, and the number of lives lost annually.¹

In investigating tornadoes, great difficulty was experienced in accurately determining property losses or loss of life, the difficulty resulting from exaggerated reports which are invariably spread over the country in connection with public calamities of this kind. For instance, the Louisville tornado of March 27th, 1890, was months later reported by the public press to have caused a loss of 500 lives instead of 185—the true number. Prof. Hazen divided the tornadoes into three classes: first, violent storms causing destruction; third, the most severe tornadoes; and placed in the second class all other known violent storms. While there were about one thousand tornadoes, each, in classes 1 and 2, causing the death of 1,071 people, an average of one person to two storms, and a loss of about \$23,000,000 in property, yet there were but 58 tornadoes of a very violent character, killing 755 people and destroying property to the amount of \$11,894,700, an average loss of 13 lives and over \$200,000 of property to each storm of class 3.

Several methods of determining the average destructive area covered by tornadoes were tested. In one case the result gives the relation between the total area visited annually by violent storms of all classes to the area of the state, with the following result: In Alabama, one square mile of *limited* destruction annually to each 7,866 square miles; Arkansas, one to 14,418; Georgia, one to 6,696; Illinois, one to 8,172; Indiana, one to 6,210; Iowa, one to 7,164; Kansas, one to 9,720; Michigan, one to 18,896; Missouri, one to 6,886; Ohio, one to 4,554; Pennsylvania, one to 9,972; Wisconsin, one to 12,042. These figures, of course, are not strictly comparable, especially when we consider the state of Ohio, which has a very large number of intelligent voluntary observers, on the one hand, and Kansas, on the other, a state not thickly settled in all sections.

Another plan followed was to consider the area of destruction covered in all well-studied and *destructive* tornadoes, and then apply that area by weight to all violent storms of each state. The following table shows the relative numbers; Alabama, one square mile of devastation or *severe destruction* to each 480,600 square miles; Arkansas, one to 712,800; Georgia, one to 504,000; Illinois, one to 185,400; Indiana, one to 880,000; Iowa, one to 482,000; Kansas, one to 486,500; Michigan, one to 914,400; Missouri, one to 406,800; Ohio, one to 248,000; Pennsylvania, one to 468,000; Wisconsin, one to 475,900. These results are materially different from those first given, and they appear more satisfactory. Such methods of comparing destroyed with undestroyed areas are, of course, incomplete, and must be received with caution.

It appears from these data that in no state may a *destructive* tornado be expected oftener, on an average, than once in two years, and that the area over which the

¹ Report of the Chief Signal Officer, U.S. War Department, 1890.

total destruction can be expected is exceedingly small even in the states most liable to these violent storms. Prof. Hazen's figures regarding the relation of destruction by fire to that of tornadoes are interesting, and worthy of consideration.

The Chief Signal Officer believes this matter of great public importance, and desires to impress upon the people at large how small are the chances of personal injury or loss of property in this connection.

It is well settled, however, that in the last eighteen years the death casualties from tornadoes average 102 annually. While this is a large number, yet it does not appear to be as great as that of the death casualties from lightning, since during the year 1890, from March to August inclusive, there were 102 lives lost by lightning, and in compiling this latter record the list is incomplete, especially as regards the Southern States. It may be safely assumed that, dangerous as are tornadoes, they are not so destructive to life as thunderstorms.

RAINFALL OF THE PACIFIC SLOPE AND THE WESTERN STATES AND TERRITORIES.

GEN. GREELY, the Chief Signal Officer, recently submitted to the United States Senate a Report on the Rainfall in Washington Territory, Oregon, California, Idaho, Nevada, Utah, Arizona, Colorado, Wyoming, New Mexico, Indian Territory, and Texas, together with 15 charts, and the corresponding data, showing the maximum and minimum for the year and the mean rainfall for each month of the year. This is also accompanied by a report by Lieut. W. A. Glassford, on the causes of the wet and dry seasons, the abundance and deficiency in different portions, the summer rainy season in Arizona, &c.

Lieut. Glassford says :—

"The season of rain occurrence notably varies in different portions of the Pacific slope. In California, Oregon, and Washington there is a marked dry season during the summer, which lengthens in duration to the southward. In Arizona there are two rainy seasons, one in midsummer, the other during the colder portions of the year. Between the Rocky and Sierra Nevada ranges of mountains the rainfall is rather uniform, but with an increasing tendency during the winter.

"That part of the Pacific slope west of the Sierra Nevada and Cascade ranges is the most highly favoured with rain. As seen in the charts the most noteworthy peculiarity is the summer drought. Summer showers and thunderstorms occur, however, in the mountain regions of Northern California, also in Oregon and Washington west of the Cascades. There is a general increase in frequency of summer rains from south to north, and the drought shortens in duration in the latter direction.

"Frequently not a sprinkle of rain falls in the Sacramento or San Joaquin Valleys, nor in the Southern Counties, from May to October. This periodic division of rainy and dry weather during the year has brought into use the term 'wet and dry season,' and references to rainfall measurements are generally understood to commence with the rainy season, and the term seasonal instead of annual is invariably the current estimate. In the great valley of California the expectation of rainless summers admits of the uninterrupted cereal harvest, its sacking and shipment, to be made without fear of damaging rains. It is an ordinary sight, during the harvest season and after, to see millions of bushels of grains sacked and piled without shelter in fields or on open cars.

"The system of mountains and valleys in Oregon and Washington Territory being similar to the district just discussed, the rainfall differs but little except in amount. There is distinctly a wet and dry season west of the Cascades, as well as in California. The wet season is characterised by either downpours or drizzly weather, and the dry seasons by scattered showers. The periodic feature of rains continues near Vancouver Island, and northward in a lesser degree, for at Sitka the rain is nearly equally distributed throughout the year.

"In the plateaus of Arizona the rainy season comes in the summer months."

Gen. Greely in his Report says :—

"An examination of the charts of maximum annual rainfall and minimum annual rainfall of these regions shows clearly that rainfall conditions are con-

siderably more equable than has been generally believed, so that the isohyetal lines are quite as regular on these charts of maxima and minima conditions as on those of average conditions. The minimum rainfall has never reached zero for any year, and annual or seasonal rainfalls less than one inch have occurred in South-western California and South-western Arizona at few stations only. These maps of maxima and minima precipitation must be of great practical value, as showing the settler or investor exactly the extreme conditions which he must expect to experience in these regions.

"It is well known that enormous quantities of water occasionally fall in these arid regions, the phenomena being known as "cloud-bursts." These downpours of rain, while injurious and even destructive at the time, yet being taken up by the earth, they serve usefully later as a water supply, through the medium of rivers, artesian wells, or springs. The quantities which fall in a single cloud-burst cannot be calculated, but the amount can be expressed by no other word than enormous. In South-eastern California, in the desert country, where it has been said that no rain falls, one cloud-burst was of such extent that, although the country was nearly level, yet water fell in such enormous quantities that over a quarter of a mile of the Southern Pacific Railroad was completely swept away, and other portions of the track submerged and damaged. It is to be noted also that this quantity of rain fell during one of the dry months, when the rain-map showed for Southern California only .01 or .02 in. of rain, barely enough to moisten the surface of the sandy desert.

"The question of increasing rainfall in the Great Interior Basin seems to be satisfactorily settled as far as the catchment basin of Great Salt Lake is concerned. The systematic and careful observations made by Prof. G. K. Gilbert, of the Geological Survey, supplemented by other data for the past forty years, which he has collated and sifted, gives with tolerable accuracy the level of the Great Salt Lake, which serves as a reservoir for probably two-thirds of the entire territory of Utah, as well as for a considerable portion of Idaho. A chart kindly furnished by Prof. Gilbert shows that Salt Lake fell from 1845 to 1849; rose to 1856, fell to 1860; rose to 1873, and fell, with a slight interruption, until 1884, and rose until 1886, since which time it has a slightly falling tendency. It is significant that while the first two minima were substantially the same in 1849 and 1860, yet the minimum of 1884 is at about the same height as the maximum of 1856, and is over a foot above the maximum of 1845. As the country adjacent to the lake is substantially level, it follows that any increase in the height of the water must be most gradual, since the area of the lake, and consequently the evaporating surface of water, is largely increased. This consideration would not be so important in some portions of the United States, but in a region where the annual evaporation cannot be far from 6 or 7 ft., it is a very pertinent fact.

"The changes in the level of Salt Lake are perhaps best shown by five-year periods, beginning with 1845. The elevation above zero (lowest water-level) for five-year periods is as follows:—

	Ft.		Ft.		Ft.
1845 to 1849	2.1	1860 to 1864	3.6	1875 to 1879	11.5
1850 to 1854	3.4	1865 to 1869	9.6	1880 to 1884	6.4
1855 to 1859	5.2	1870 to 1874	12.6	1885 to 1887	8.2

"It is a significant fact, which may, however, be overrated, that the greatest and most rapid rise of the water of Salt Lake occurred between the years 1862 and 1870, that is to say, during the period when the amount of land being brought under cultivation and the quantity of vegetation and the number of trees were most largely increasing. This increase of height in Great Salt Lake continued, too, despite the fact that irrigation canals were being brought into extensive use, so that large quantities of water which otherwise would have run into the lake were diverted to watering the irrigable (sic) lands, and were absorbed by the soil or evaporated in the dry air of that region."

RECENT PUBLICATIONS.

AMERICAN METEOROLOGICAL JOURNAL. Vol. VIII. Nos. 1-2. May and June 1891. 8vo.

Contains, among other articles, the following information:—Cold Waves: by Prof. T. Russell (8 pp.).—Parhelia and Paraselenæ at Grand Forks, North Dakota: by Prof. L. Estes (2 pp.).—How could the Weather Service best promote Agriculture?: by Prof. M. W. Harrington (8 pp.).—Is the Influenza spread by the wind?: by Dr. H. H. Hildebrandsson (5 pp.). The result of the author's investigation is that the influenza is propagated by infection, and conducted from place to place through human circulation, and that the time of incubation is two to three days. The state of the weather seemed to have had no influence on this sickness. In fact the influenza raged with the same severity in countries possessing very different climates, and during very different weather conditions.—An ink recorder for the electrical anemometer: by S. P. Fergusson (2 pp.).—A brief notice respecting Photography in relation to meteorological work: by G. M. Whipple (6 pp.).—Application of Photography to meteorological phenomena: by W. Marriott (7 pp.). These two papers have been reprinted from the *Quarterly Journal of the Royal Meteorological Society*, Vol. XVI., July 1890.—New England Meteorological Society (20 pp.). This gives the papers read at the meeting held on April 18th, 1891, when the subject for discussion was Weather Prediction.—Weather Prediction in the States and its improvement: by M. W. Harrington (10 pp.).—Farwell's Rainfall scheme (7 pp.).

BIHANG TILL KONGL. SVENSKA VETENSKAPS-AKADEMIENS HANDLINGAR. Band XVI., Afd. 1. No. 5. 1891. 8vo.

Contains: Études des conditions météorologiques à l'aide de cartes synoptiques représentant la densité de l'air: par N. Ekholm (86 pp. and 18 plates). Dr. Ekholm has traced for a number of days lines which he now calls *isodenses*, representing the density of the air calculated according to a formula which he gives. He finds, speaking generally, 1. That the isodenses run parallel to the coasts. 2. That whenever a depression exists the rarefied air is found to the south and east of the centre, and the dense air to the north and west. If these are not strongly marked the depression has slight intensity, and *vice versa* when they are strongly contrasted. 3. If a contrast between densities of the air in districts close to each other appears, a depression will be found there. This was notably the case in the cyclone of October 24th, 1882, which appeared suddenly over the Channel, and Dr. Ekholm gives other similar examples from Scandinavia. He finds, as regards probable direction of advance of depressions, that it is generally the case that they advance along the tangent to the isobars at the point where the gradient is steepest, and in the direction of the wind there. If the isobars are uniformly distributed round the centre, it will be found that the cyclone will advance along the isodenses, leaving the rarefied air on its right-hand side.

CYCLONE MEMOIRS. Part III. Published by the Meteorological Department of the Government of India, under the direction of J. ELIOT, M.A., Meteorological Reporter. 1890. 8vo. 165 pp. and 29 plates.

This contains an account of the cyclonic storm of September 18th to 20th, 1868, and of the cyclone of October 27th to 31st, in the Bay of Bengal; and the cyclone of November 6th to 9th, 1888, in the Arabian Sea. Mr. Eliot says that the following appear to be some of the more important inferences with regard to the constitution and motion of the cyclonic storms, and, therefore, probably of cyclones generally in the Indian area:—1. That the winds differ considerably in intensity in different quadrants, and that this difference is mainly caused by the fact that the humid winds which maintain the vigorous circulation of the cyclone enter mainly in one quadrant. 2. The amount of ascensional movement or uptake differs very considerably in different quadrants, and is usually most rapid and vigorous in the advancing quadrant at some little distance in front of the centre. 3. In consequence of ascensional motion and rainfall taking place most vigorously in the advancing quadrant, or in front of the cyclone, the isobars

are oval in form, and the longest diameter coincides approximately with the direction of the path of the centre. The centre of the cyclonic circulation and of the storm is not in the middle of this diameter, but is at some distance behind. As a further consequence, the gradients are steepest in the rear of the storm centre. 4. A consideration of the relations stated in the preceding show that a cyclonic circulation cannot be resolved into the translation of a rotating disc or mass of air. The fact that the main supply of the energy is applied in front of the cyclone suggests that it is perpetually renewed in front, and that, in fact, its motion and transmission are hence rather to be explained by some process analogous to the transmission of a wave. 5. The direction or line of advance of these storms appears to be mainly determined by the rainfall distribution. There is a very marked tendency for storms to form in and to run along the south-west monsoon trough of low pressure, if it be in existence at the time of the formation of the storm. 6. The line of the south-west monsoon trough of low pressure at any time, and hence also of the most probable tracts of cyclonic storms at that time, depends upon the relative strengths and extension of the two currents. When both are blowing strongly, as is usually the case in July and August, the most probable direction of motion of a cyclonic storm at such a time is west with a slight curving to north, if the storm continues its course westwards after passing into the Central Provinces. If the Bombay current be weak, the storm will probably either break up in the Central Provinces or recurve rapidly to north.

METEOROLOGISCHE ZEITSCHRIFT. Herausgegeben von Dr. J. HANN und Dr. W. KÖPPEN. April to June 1891. 4to.

The principal articles are:—Die Hagelschläge des 21 August 1890 im Steiermark: von Prof. K. Prohaska (8 pp.). This is an account of the phenomena in Styria which accompanied the whirlwinds and hailstorms in France and North Italy which have already been noticed in this Journal. Prof. Prohaska gives an account of three storms with terrific hail which passed along the same tract between 5 and 7 p.m. on that day. The hail was of the size of goose eggs in some cases, and masses of stones were frozen together by regelation in courtyards to the depth of a metre, and you could hardly push a stick into them. The contour of the country had no influence on the track; it was determined by the isobars and went straight over mountain and valley. Its speed was greatest over flat country, so that mountains retarded it. Among the most interesting observations was that of the clouds; before each of the storms masses of cloud were sucked in towards the approaching storm, and moved with great rapidity. The thunder and lightning was very slight.—Die Luftdruckverhältnisse von Krakau nach den stündlichen Barographen-Aufzeichnungen (1858-1888): von Dr. R. B. Buzsaczynski (7 pp.).—Eine Beziehung zwischen dem Luftdruck und dem Stundenwinkel des Mondes: von R. Börnstein (10 pp.). This is an attempt to connect the barometer with the lunar day. Dr. Börnstein has taken the continuous records for several years for Vienna, Berlin, Hamburg, and Keitum in Sylt. He gives the following results: 1. The existence of an atmospheric tide is not traceable in the barometer records. 2. At Berlin, Hamburg, and Vienna, he finds a single oscillation of which the minimum occurs at moonrise. This is true also at Keitum, but there the curve shows complications which Dr. Börnstein is disposed to connect with the tidal phenomena of the sea, but says that he requires a much longer series of observations than the 10 years he has available to establish this relation.—Bemerkungen eines Statistikers über meteorologische Mittelzahlen: von K. Brämer (8 pp.). This is a note by a statistician on the best mode of interpolation to fill gaps in meteorological observations, particularly of the barometer, and it contains at the end some valuable remarks, probably by Dr. Hann, which are well worth a study.—Resultate der meteorologischen Beobachtungen auf dem Gipfel von Pike's Peak (Colorado) 4,808 metres (14,184 feet) nach Beobachtungen von November 1874 bis inclusive Juni 1888: von J. Hann (20 pp.). This is an analysis of Pickering's Publication in the *Annals of the Harvard College Observatory* published out of the Boyden Fund. Dr. Hann gives long extracts from the daily journals to show what the experiences of the observers were, and translates Mr. Abercromby's account of his visit. It is remarkable that mountain sickness attacked almost everyone, though elsewhere it does not prevail at the height of 14,000 feet.—Eduard Brückner: Klimaschwankungen seit 1,700, nebst Bemerkungen über die Klimaschwankungen der Diluvialzeit (9 pp.). There are two papers on the oscillation

of climate in the June number. The first is by Dr. Kremser, and is a summary of Prof. Brückner's book of which the title is given above. The second is by Prof. Brückner, and is a notice of Richter's *Geschichte der Schwankungen der Alpengletscher*, which appeared in the *Journal of the Alpenverein* for the present year (8 pp.). Brückner deals firstly with the oscillation of large lakes like the Caspian as far as he can get data, and then treats of rainfall since 1880. He finds a 85 year period, and also maintains that at the glacial epoch the mean temperature was not more than 8° F. or 10° F. lower than at present. Richter's independent inquiry deals with the glaciers. He finds also a mean oscillation of 85 years, and he maintains that all the stories of passes now closed by ice having been used in past ages, are not corroborated by any evidence now to be found.

REPERTORIUM FÜR METEOROLOGIE. Herausgegeben von der Kaiserlichen-Akademie der Wissenschaften. Band XIV. No. 9. 1891. 4to.

This contains a paper by Dr. Wild, entitled "Ueber den Einfluss der Aufstellung auf die Angaben der Thermometer zur Bestimmung der Lufttemperatur" (71 pp. and 2 plates). This is a contribution to a much discussed subject. Prof. Wild, however, has not on this occasion compared any of the modes of exposure employed in Western Europe. He has taken (1) his own screen composed of two concentric cylinders of zinc. 2. A screen, called by him the *louvre* screen, made of sheet brass and partially louvred. 3. A screen made of brass like No. 1, erected on north side of observatory. 4. A set of thermometers suspended on a post at different heights and separated from each other, and screened from the sun by sheet brass; this protection being rotated to suit the sun's position. As to instruments, he employed, in addition to ordinary thermometers, Hasler's metallic thermometer, Richard's thermograph, and Negretti and Zambra's turn-over thermometer; ventilation was applied in all cases where it was possible. The comparisons are set out in very great detail. The final conclusions are for annual means: 1. The *louvre* screen gave right results with and without ventilation. 2. The Wild screen gave without ventilation a mean 0·1 centigrade too high. The brass screen on north side of house ventilated gave 0·1 too low; the thermometers on the post gave means too low. A thermometer lying on the bare ground or on snow in winter gave a mean 1·8 too high. These general results show considerable variation according to the season, and even greater when examined from the point of view of diurnal range, but for these details we must refer to the original paper.

SYMONS'S MONTHLY METEOROLOGICAL MAGAZINE. April to June 1891. Nos. 808-805. 8vo.

The principal articles are:—The great snowstorm of March 1891 (7 pp.). The area visited seems to have been a belt about 120 miles wide, extending from about Cheltenham on the north to Jersey on the south, or say from Colchester on the north to Dieppe on the south, and reaching from the south of Ireland eastwards to Holland. The snow was much deeper in Cornwall and Devonshire than anywhere else.—The theory of halos and *parhelia*: by the Rev. A. K. Cherrill (12 pp.).—A changeable May (4 pp.).

TRANSACTIONS OF THE SANITARY INSTITUTE. Vol. XI. 1890. 8vo. 852 pp. 1891.

This is principally a record of the Congress held at Brighton in August 1890. The meteorological papers were:—The climate of Brighton: by F. E. Sawyer (9 pp.). This is a summary of 21 years' observations, 1868-1888.—Teneriffe as a health resort: by G. W. Struttell (6 pp.).

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EDITED BY A
COMMITTEE OF THE COUNCIL.

OCTOBER 1891.
VOL. XVII. No. 80.

LONDON:
EDWARD STANFORD, 26 & 27 COCKSPUR ST., CHARING CROSS, S.W.;
WILLIAMS AND STRAHAN, 7 LAWRENCE LANE, CHEAPSIDE, E.C.

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ESTABLISHED 1850. INCORPORATED BY ROYAL CHARTER, 1866.

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QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY.

VOL. XVII.

OCTOBER 1891.

No. 80.

ON THE VERTICAL CIRCULATION OF THE ATMOSPHERE IN RELATION TO THE FORMATION OF STORMS.

By W. H. DINES, B.A., F.R.Met.Soc.

[Received January 3rd.—Read May 20th, 1891.]

It is doubtful whether a correct knowledge of the causes which originate and maintain a cyclonic disturbance would be of much practical importance in the way of enabling better forecasts to be made, but the subject is one of such great interest, and also it may be said of such complexity, that a discussion of the problem should be welcome.

There are certain facts relating to these storms which are well known, and with which any theory on the subject must agree; there are also certain well-established mechanical and physical laws, amongst which the principle of the conservation of energy stands first, without reference to which an inquiry into the causes of the phenomena is impossible.

It is admitted on all hands that the unequal heating of the surface of the earth by the sun's rays is the primary cause of all wind, but considerable uncertainty prevails as to the exact method by which the final result is brought about.

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P

At first sight it appears strange that the warmest strata of the air should be those lying nearest to the earth's surface ; with sea water the exact opposite holds, the coldest water being at the bottom of the great oceans, and the warmest at the surface. Equilibrium is impossible with a layer of warm water lying below a layer of cold, and the same is true of air provided the two layers be at the same pressure. In the atmosphere the air is compressed by the superincumbent mass, and as we ascend the pressure becomes less, the change at sea-level being about one-tenth of an inch of mercury for every 90 ft. When the air becomes subject to a decrease of pressure it expands and at the same time becomes cooler, and the amount of cooling which will occur from this cause when dry air is raised 90 ft. above sea-level is about $0^{\circ}\cdot 5$.

It is strange that a fact so well known should be often ignored, but since it is so, it may be well to point out that this cooling does really occur. The common experiment showing the condensation which occurs in the receiver of an air pump may be cited. In this case the air rapidly assumes the temperature of the walls of the receiver, and the cloud disappears almost as soon as it is formed. If another proof be required it may be found in a study of the method of obtaining the low temperature by which meat is carried through the tropics, the storage rooms being kept considerably below the freezing point by the expansion and consequent cooling of air. This principle is of great importance in meteorology, for it is due to it that the air in contact with the earth is generally warmer than the air above. The question whether air will ascend depends not upon whether it is warmer than the air above it, but upon whether it is so much warmer that after its ascent, expansion, and cooling, it will then be warmer than the air at its new level.¹

Under ordinary circumstances this ascent of warm air will not occur, for dry air when raised in height generally becomes cooler than the surrounding atmosphere, and conversely dry air in descending generally becomes warmer.

It is not necessary that the change of pressure should be produced by a change of altitude ; change of locality from a position of high to a position of low barometrical pressure will have the same cooling or warming effect, hence, unless other circumstances of more importance interfered, a higher temperature would always be found to accompany anticyclonic conditions of weather.

The rate of cooling given above refers only to dry air ; it must also be remembered that although expanding air is invariably cooled in virtue of its expansion, yet it may happen that it is at the same time receiving heat from some external source, by passing over warm land or sea for example, so that the final result may be an increase of temperature.

When air containing vapour expands and cools, the change of temperature follows practically the same rule as that which applies to dry air until condensation occurs. As soon, however, as a cloud is formed, the latent heat set free by the condensation checks the cooling process, and the decrease of temperature proceeds much more slowly ; and thus it happens that the change of tempera-

¹ Deschanel's *Natural Philosophy*, Part II. p. 502.

ture in a vertical direction is often such that moist air after ascending, cooling, and condensing some of its vapour, is still warmer than the surrounding air at its own level. Under these circumstances an upward convection current is formed, and according to the theory which has been so ably brought forward by Prof. Ferrel, this is the chief cause of a cyclone.

Turning now to the storms themselves, it is well known (1) that they do not occur on the Equator; (2) that, speaking roughly, the winds blow in circles round the central barometrical depression; (3) that there is a decided indraft of air towards the centre, the wind directions being more or less inclined to the isobars; (4) that the central parts are generally characterised by clouds and rain.

Without entering into any strict calculation it is easy to see that, whatever the cause of the storm, the centrifugal force due to the circular motion must be accompanied by a decrease of pressure at the centre. It follows also from (3) that there must be a decided upward motion of the air somewhere in the central parts, for if this upward current is denied it is impossible to say what becomes of the air which is continually moving towards the centre. It cannot become annihilated, neither can it sink into the ground, it must therefore ascend and flow out above.

It will be well now to trace as far as possible the changes of temperature which accompany the vertical circulation.

In rising in the central parts the change is probably adiabatic, for there is nothing in contact with the air to which it can give, or from which it can receive heat. It can hardly lose heat by radiation, or receive it by the direct action of the sun's rays, for, as a rule, the ascending current is covered by a dense layer of clouds. Dr. Hann thinks that the air is cooled by the cold rain or snow falling from a higher level, but it appears to me that this is only partly the case. Raindrops descend with a nearly uniform velocity, which never reaches a very high value, even with the largest drops, and it is known that if the velocity of a drop is not increased it is warmed 1° by friction with the air for every 772 ft. that it falls, or if not warmed it imparts an equivalent amount of heat to the air. My father made many observations on the temperature of rain, and found it invariably above that of the wet bulb, and generally above the temperature of the dry bulb thermometer. The falling drops must, however, to some extent impede the upward flow of the air. The adiabatic rate of cooling depends on the amount of moisture and the temperature. Tables have been drawn up by Dr. Hann and translated by Prof. Abbe (*Smithsonian Report 1877*) showing the amount under various conditions. Without entering into details, it is sufficient to remark that the air in ascending is cooled through a considerable range of temperature, but that, owing to the latent heat set free by the condensation which forms the clouds and rain, it is not cooled so much as dry air would be in rising to the same height.

There is reason to think that the air in its passage as an upper current to anticyclonic regions is considerably cooled by radiation into space. It carries with it a certain amount of water in the form of ice crystals, which we see as cirrus cloud. Pure snow is but very little affected by the sun's rays, the heat being reflected, but it is a very good radiator, and therefore it is probable

that the cirrus cloud, and through it the air in which it floats, is cooled by radiation to a greater extent than it is warmed by the sun.

In descending from the higher level the air is doubtless warmed by the increase of pressure. If the change of temperature be purely adiabatic, the rise of temperature will exceed in amount the fall which occurred in the ascent; for in this case there is no water to be evaporated, and thus use up the heat, the equivalent of which was given out by condensation in the ascending current. It seems probable that the change is adiabatic, for air is a bad radiator, and dry air allows the sun's rays to pass without absorbing much heat. There are, however, two points to be remembered; since the region of the descending current is anticyclonic, there is no upper cloud covering to prevent radiation; and also the current probably occupies a much larger space than it did in ascending, hence it has a smaller velocity and more time is allowed for radiation to take effect.

In passing near the earth's surface from a region of high pressure towards the centre of a storm, the air does not travel in a straight line; it therefore comes in contact with a large extent of surface, throughout different parts of which widely different temperature conditions prevail. Hence it is impossible to say what change of temperature will occur by contact with the earth's surface, but it may safely be asserted that this contact will be the predominant factor in the determination of the final temperature. Two points also are clear, the air will be cooled in virtue of the decrease of pressure to which it is subjected in approaching the centre, and also in its passage it will receive a large amount of moisture and reach the centre as a damp wind: this will be the case particularly where the course has been over the sea or wet ground.

The above rough outline of the circulation has been given without reference to the causes which produce it, or to the various influences which often largely modify the result; it is, however, I think fairly applicable to the average case.

Two theories have been suggested to account for the phenomena of storms. One, the convectional theory, is that the central air rises in consequence of its greater relative warmth, this warmth being produced by the latent heat set free by condensation. It must be remembered that an absolutely higher temperature in the centre is not required, but only such a temperature that, after the adiabatic heating produced by a change of position without change of level to regions of higher barometrical pressure the air, may then be warmer than the strata lying at its own level. Thus, if the depression of the mercury in the centre be one inch, this difference of pressure will account for a difference of 5° of temperature, and thus air in the centre will rise, unless it be more than 5° below the temperature of the air outside the depression at its own level.

It can be shown that if from any cause an upward current be established, the air rushing in to supply its place will receive, in consequence of the rotation of the earth (unless the locality be close to the equator), the eddying circular motion characteristic of a cyclone,¹ so that the convectional theory, whether true or not, is capable of producing the effect.

¹ *Routh's Rigid Dynamics*, Chap V. p. 264 and f.

The other theory is that the storms are circular eddies produced by the general motion of the atmosphere as a whole, just as small water eddies are formed in a flowing stream of water. If an eddy of this kind were produced in the upper air it would, owing to the centrifugal force, lessen the air pressure at the centre, the air below would rise, and the eddying motion would soon extend to the earth's surface.

It appears to me that the convectional theory is the most probable, for according to it a copious supply of moisture is required to maintain the energy of a storm, and it has often been noticed that these storms follow the course of the Gulf Stream, where the moisture is supplied by the warm sea water. A short study too of the secondary disturbances which often appear in winter will show that they exhibit a decided preference for the sea, often travelling up the English Channel or down the North Sea, in preference to passing over the land. This theory also explains the permanency of wet or dry weather when once thoroughly established, for dry weather having once set in, the moisture required to maintain a cyclonic disturbance is absent, and conversely the place where the air and ground are damp from previous rain is the place over which a storm is most likely to travel.

The other theory will equally well explain the formation of rain at the centre, produced by the dynamic cooling of the ascending current; it is also easy to suppose that the storm would be most violent over the sea where the surface wind is least impeded by friction, but it seems to me that to prove it to be the true theory it is necessary to show that storms are most numerous on the lee side of mountain ranges, that is to say on the western side in the tropics, and the eastern in temperate latitudes. Eddies in a stream are most frequent where the even flow of the water is disturbed by irregularities in the sides or bottom, and apparently the same rule ought to hold for air.

Unfortunately, we have very little information about the temperature of the upper air. Mountain observatories throw some light on it, but of course they cannot exist over the sea, where the results would be especially interesting. Again, it is a question whether the temperature observed on a mountain is identical with the average air temperature at the same level. Probably the two temperatures would agree in windy weather, but it is doubtful whether they would do so in a calm. A knowledge of these temperatures would afford a direct proof or refutation of the convectional theory, but it is difficult to see how this knowledge can be obtained.

DISCUSSION.

Mr. GASTER said that it was very difficult to follow this paper, as it was one which required very careful consideration, and could not be adequately discussed after hearing it merely read through once. He took exception to the statement that temperature in an anticyclone is higher than in a cyclone. In the winter months, at all events, the condition is exactly the reverse, and he should wish for statistical evidence before accepting the statement as it stood. The determination of the true temperature of the air in cyclones and anticyclones is surrounded with difficulties. With an anticyclone there is, as a rule, little cloud, and the radia-

tion of heat from the earth's surface at night and in winter is then very large; the question which arises is, therefore, how much of the cold observed under such circumstances is due to radiation, and how much to the downrush of air. A cyclone is accompanied with a very cloudy sky and often rain, so that there is little radiation. He had an idea that a series of good simultaneous temperature observations taken at sea, where the effect of radiation both terrestrial and solar is exceedingly small, would greatly assist in solving the question whether the low temperature in the centre of an anticyclone is due to the downrush of cold air from higher regions, or to the effect of radiation.

Capt. WILSON-BARKER said that he agreed, to a certain extent, with Mr. Gaster's remarks concerning the relative temperature of cyclones and anticyclones. He thought that Dr. Hann had gone too far in the conclusions he had drawn from the results of observations made at mountain observatories, for he (Capt. Wilson-Barker) believed that such observations might at times be very misleading in studying the question of the vertical circulation of the atmosphere. Observations taken at sea would be of great value; and now that captive balloons were being used by ships, he thought we might hope for some light to be thrown on the subject of the vertical circulation in the atmosphere, in a manner which could never be attained by observations over the land. He was glad to see that Mr. Dines had taken up the subject.

Mr. BRUCE said that balloons could undoubtedly be of great service in investigating atmospheric conditions at various elevations above the earth's surface; and for such a purpose it would not be necessary to use large balloons, such as would carry persons, but small balloons of sufficient capacity to carry a few instruments would be all that need be used.

Inspector-General LAWSON drew attention to Col. Reid's description of the great hurricane which occurred at Barbadoes on August 10, 1881, and described the circulation of the air as indicated by the wind changes experienced at the various places which came under the influence of this hurricane. This commenced in the immediate vicinity of Barbadoes: in the evening its centre passed over that island, and travelled between St. Vincent and St. Lucia. During this course the winds which occurred were mainly from the North-east, then, after a short lull, from North-west, and after another lull, from the South-west, the first and last being aerial currents seen almost every day at Barbadoes, and that from the North-west between the other two, and visible occasionally only. All the changes occurred at Barbadoes; at St. Lucia the North-easterly gale was met with at the north end of the island, at its south end this was followed by a South-westerly one; and at St. Vincent the hurricane commenced at North-west, and shifted to South-west, then backing to the South-east gradually ceased. At Barbadoes, during the violence of the gale, the wind backed about eight points each shift; at St. Vincent a similar quantity, but at St. Lucia sixteen; but nowhere was there a gradual shift, as it is usually supposed to do in a circular storm.

Mr. C. HARDING said that he was very glad that Mr. Dines was working on the same lines as Prof. Ferrel, in America, as a worker at home in this direction was much needed. He did not think Mr. Gaster's idea of organising air temperature observations over the sea was at all necessary, for if provided with the temperature of the sea, he could give a very close approximation to the temperature of the air immediately above it. Mr. Gaster had said that the sky was clear when anticyclonic conditions prevailed, but during December last, when the weather in the British Islands was under the influence of a large anticyclonic area, the sky was completely overcast during nearly the whole of the month. He heartily believed in balloon observations, and only wished that somebody would work up all the observations which had already been made, especially those of Mr. Glaisher. It was often found by balloonists that the changes in the temperature of the various strata of air passed through were very irregular. Mr. Glaisher had found that when an ascent was made in the evening the air temperature increased for some considerable distance from the earth's surface instead of decreasing. He (Mr. Harding) was firmly persuaded that it was imperative that meteorologists should thoroughly study the laws which governed the movements of cyclones and anticyclones.

The PRESIDENT (Mr. Latham) said that he did not believe much in the convection of air. He had been told when making some experiments on underground temperature, for which purpose long tubes sunk in the ground were used,

that he would have to make some allowance for the convection of air in these tubes, but he had not found it necessary to apply any correction whatever to the observations, which extended over a number of years.

Mr. GASTER remarked that he had understood Mr. Dines to say that the air travelled three or four times round the central area of a cyclone. He had never observed such an occurrence, and should much like to have such a case pointed out to him.

ON BROCKEN SPECTRES IN A LONDON FOG.

By A. W. CLAYDEN, M.A., F.R.Met.Soc.

[Received March 18th.—Read May 20th 1891.]

In October 1887 a paper¹ was read before the Royal Meteorological Society by Mr. Henry Sharpe upon *Brocken Spectres and the Bows which sometimes accompany them*. This interesting communication contained a large number of descriptions of the somewhat rare phenomenon, and from them the author drew certain conclusions.

Some points, however, he left without any attempt at explanation, notably the dark rays occasionally seen in prolongation of the arms of a "spectre," or in some other way connected with it.

Moreover, although he showed reasons for believing that the assignment of enlarged size to the shadow was due to an error of judgment in estimating its distance, he offered no suggestion as to the reason for an error of very frequent occurrence.

These two points I have often thought over, until I was led to the formation of a theory by which they seemed explicable. Several times have I begun to commit my ideas to writing, but only to abandon the attempt in the hope of obtaining some experimental evidence to lend them support.

With this object in view I have repeatedly tried to raise my own "spectre," but for a long time with indifferent success.

Frequently I have fancied I could just make out my shadow on a fog at night by the light of a gas lamp. Three times also I have dimly seen a similar appearance by standing on the roof of my house when a fog was clearing, so that it still lay thick upon the ground while the sun was shining with a feeble lustre around me. None of these shadows, however, were clear enough for my purpose. I was conscious of their presence, but could see no definite details.

On the night of February 17th, 1891, I was looking at such a faint shadow thrown by the light from a railway-carriage lamp, and it struck me that in

¹ *Quarterly Journal*. Vol. XIII. p. 245.

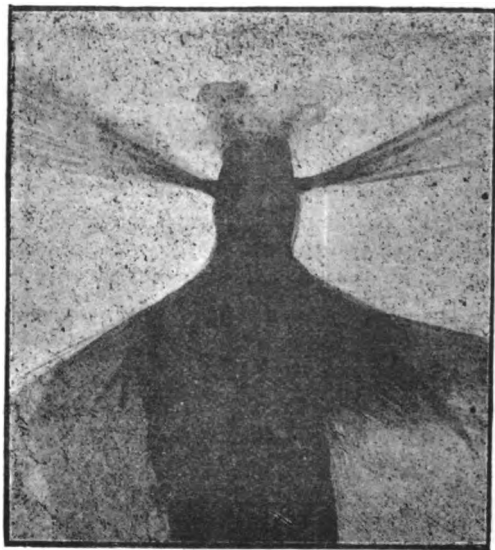
order to see it plainly all that was wanted was a brighter light and protection from cross-lights.

The Saturday following there was fog, so I went out into my garden and got my brother, Mr. C. E. Clayden, to burn some plaited strands of magnesium ribbon a few feet behind me. Instantly there stood the long-sought "spectre." Its head was sharply defined, its body fairly so, but the brim of its hat was prolonged into long shadowy horns growing fainter and broader towards their tips. Its arms could only be seen as indistinct masses of shadow when they were moved. There was a slight accession of light near the head, but no coloured glories and no bow.

The diagram (Fig. 1) gives a fair idea of what I saw.

Having found that the phenomenon could be produced, I substituted a steady lime-light for the sputtering magnesium and then called out my household to come and say what they saw. Each gave much the same description.

FIG. 1.



No one could see the shadow of any other, and if two of us stood close together our shadows merged into one. Thus, when my wife stood close to my right side, the left-hand margin of my spectre was unchanged, but on the right it simply faded away in broad masses of light and shade.

I made several attempts to photograph the appearances, fixing the camera close in front of myself so that the lens should lie as nearly as possible in the same position as my eye. None of these plates were sufficiently exposed, and the fog cleared before I could try again.

Monday the 23rd brought a denser mist, so I determined to make the camera photograph its own "spectre," placing a hat on top of the apparatus

to show the dark rays in continuation of its brim. Exposures of 10 and 15 minutes gave satisfactory results, and I am glad to be able to show prints from the negatives.

Whilst the photographs were in progress I made some measurements of my shadow. The head, about level with the ears, subtended the same angle as 2 ins. at a distance of 12. A faint white bow visible on this occasion had an angular radius of 45° to its inner margin and 52° to its outer edge. No trace of colour could be detected.

I noticed that the fog particles were so large, that within a foot of the light, where they were illuminated with great brilliancy, the individual droplets were plainly visible. The fog was very wet, everything being saturated with moisture, and the temperature about 89° .

I found that if I breathed heavily, so that the condensed vapour drifted across the shadow, fragments of circular glories appeared fringing the head of a larger shadow than that on the fog. Indeed, I could see the fog shadow through the one cast on my breath. In a similar way, when I poured some hot water over a broom and waved it at arm's length on the windward side of the shadow, the veil of dense mist which drifted from it gave a shadow intermediate in size but no glories.

One more observation was made, namely that if I stood about 8 or 10 ft. from the light the outlines of the shadow were very distinct, but they became less so as I moved away, until at a distance of about 20 ft. not a vestige of shadow could be seen. All parts of the fog seemed about equally illuminated by the irregular reflection of light from the particles nearer to the light.

When I measured the angular width of my spectre I asked the others to say how far away their shadows seemed to be. After a little hesitation all agreed that they seemed to be "about half across the garden," that is about 25 or 20 ft. The size was gigantic enough, but then the light was radiated almost from a point. My own estimate was fully in accordance with the above, but I felt that it was quite impossible to feel any confidence in the judgment of the distance of such an intangible and rather vaguely defined object.

When the mist became thinner, the spectre seemed to retire, and its angular width became less. The dark rays were always present.

The observations suggest three questions:—

Did we estimate the distance of the shadow correctly? If not, how were we led astray? What were the dark rays?

Now there are two ways of getting an answer to the first question—from the angular measurement of my shadow, and from the photographic image.

First take my shadow.

The semi-diameter of the head subtended an angle equal to 1 in. at a distance of 12. This is an angle of about $4\frac{3}{4}^\circ$.

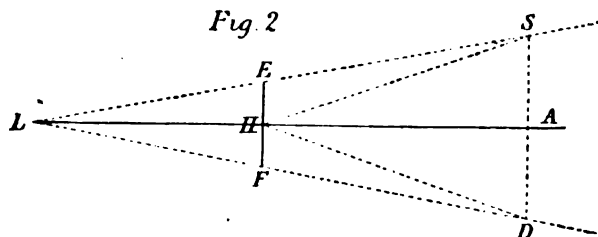
The corresponding half-width of my head to the outer margin of the ears is about $8\frac{1}{2}$ ins., and the light was about 100 ins. behind. Hence the angle between the line from the light to the centre of my head and the ray which just grazed my ear must have been about 2° .

Thus if L (Fig. 2) is the light and EHF my head, the angle ELH is 2° .

Also if H represents my eye, and the angle DHS the angular width of the shadow, the angle AHS is $4\frac{1}{2}^\circ$. Hence LE and HS will meet at some point, which must be the actual edge of the "spectre."

Now we have a triangle SLH , the angles of which are known, and the relative length of the sides can be calculated, so giving the distance HA . This comes out about 6 ft.

Now take the photograph.



Here the data are :—focus of lens $5\frac{1}{2}$ ins.; width of hat $9\frac{1}{2}$ ins.; width of corresponding image $1\frac{1}{2}$ ins.; distance of light 70 ins. From these figures the semi-diameter of the hat subtended an angle at the light of about $8\frac{1}{2}^\circ$, while the semi-diameter of the shadow gave an angle at the lens of $7\frac{1}{2}^\circ$. A computation similar to that above given again gave a distance of about 6 ft.

Of course all measurements of the angular diameter of the shadow or its image can only be approximately correct, but this fact makes it all the more remarkable that the two results should be practically the same.

Moreover, their correctness is checked in other ways. One photograph shows the shadow partly projected on a paling, partly on the fog. It is obvious that the latter portion is larger than the former. Hence it is nearer. The paling was about 8 or 9 ft. away. Again the shadow on my breath was within a foot or so of my eye, the shadow on the steam from the hot water must have been 8 or 4 ft. away, and this last was intermediate in size between the breath shadow and the fog shadow.

It therefore seems to be proved that the "spectres" were only about one quarter of their apparent distance from us.

This leads us to the second question : Why were we mistaken ? But in order to answer it, and at the same time arrive at the explanation of the dark rays, perhaps it will be best to state certain postulates which I think no one will question.

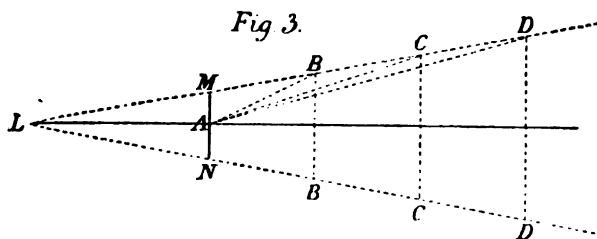
1. The brighter the illumination of a fog particle the larger it will look in consequence of irradiation ; 2. The nearer a given particle is to the source of light or to the edge of a cloud, the brighter will be its illumination ; 3. At a short distance from the source of light (or edge of the cloud) the particles are mainly illuminated by irregular reflection from particles which lie nearer. The result is that an object can then cast no distinct shadow even upon an opaque screen only a few feet distant. This point is reached long before the source of light ceases to be visible, as may easily be observed any time when

the sun is gradually dissipating a morning fog, when it can be seen, and may even be quite dazzling to the eyes, before the body can cast a distinct shadow.

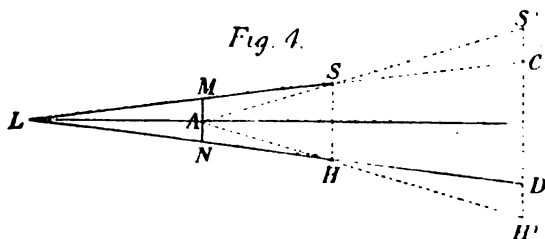
It follows from the first two statements that if a man is surrounded by fog he will be able to see only a short distance into it where the particles are brightly illuminated, but where they are shaded by his body his eye will be able to penetrate much further. Everyone must have noticed how thin a veil of brightly illuminated mist is enough to completely hide objects beyond.

When a man, therefore, looks at his shadow on a fog he is practically looking down a hole in that fog. The walls of this hole are made of bright and therefore opaque fog, while the hole itself, so to say, is filled with a mist which is comparatively transparent.

Thus if L (Fig. 3) is the light, and MN the man's head, its shadow will be marked out by the lines BCD . At B the difference of illumination will be great; at C the light outside the shadow will be fainter, and a larger proportion will be due to irregular reflection. At some distance DD , where the direct light can no longer cast a shadow, all parts of the fog will be equally illuminated, and the shadow cone will come to an end.



Moreover, as the observer looks down the shadow, its boundary will be bright at B , less bright at C , and at D the tint of the shadow wall will match that of the shadow itself. Clearly this point DD must determine the true position of the "spectre."

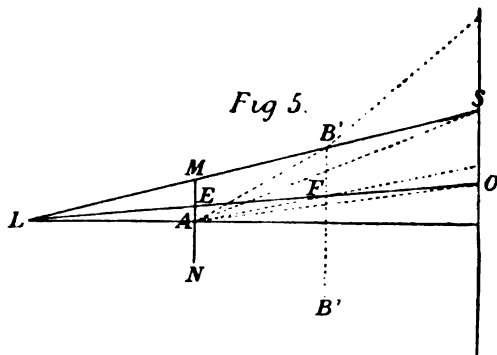


But when asked to estimate the size of the shadow he will instinctively attempt to gauge its distance, and in order to do so he will not look at the opaque illuminated fog but rather at the shadow itself where the mist is comparatively transparent. Hence it will be referred to a greater distance, with the result that its apparent size $S'H'$ (Fig. 4) will be too great.

The dark rays are simple enough. They are the gradually darkening

walls of the shadow. All parts of the spectre are really shaded off in this way, but where the true shadow covers only a small angle this shaded margin is so small as to be hardly noticed. Where, on the other hand, the width is greater, the shading will cover a wider angle.

Thus if A (Fig. 5) is the eye and AE a narrow part of the man, and if BB marks the distance at which the darkening of the mist becomes visible, and SO the position of the shadow, then the angle FAO will give the apparent



width of the shaded margin. Similarly, if MA is a wider part of the man its shaded margin will cover the angle BAS. These shaded margins are then unconsciously projected on the plane of SO. The darkest part of the ray matches the tint of the shadow and has the same dimensions, but the fainter parts of the ray shade off imperceptibly into the luminous mist, and since they are nearer to the eye they cover a wider angle and so look wider. The spreading out, in other words, is merely an effect of perspective.

It seems also that the presence of the shaded fog within the shadow may affect the tint of the shadow and its luminous walls. In one sense the shaded particles will reflect some light from outside the shadow, so lightening its tint, while, on the other hand, they will tend to obliterate some of the light which might reach the eye from particles outside the shadow. But whichever effect were the stronger, the explanation of the appearances seen would not be affected.

A reference to the figures will show that very little modification is necessary to make them equally applicable to what may be called natural Brocken Spectres, the dark rays seen by Mr. Abercromby and others, and the shadowy arms often seen, being obviously similar to the appearances we noticed. The over estimate of a "spectre's" size will be similarly explained, and the inability of one person to see another's spectre is a consequence of the fact that the observer looks through a wall of illuminated mist several feet in thickness, into its dark interior.

If a person is in a fog, he must be close to its margin or the light will not throw a shadow. If he is on its margin he will see the phenomena to the best advantage. If he is outside it, but not too far away for the details of

his shadow to be sharp, he may be able to see down the shadows of others, but will not be able to see much of the dark rays. Again, when he is in or upon the margin of the mist his shadow will appear enlarged, and its apparent size will depend upon the density of the mist and the brightness of the light. If, on the other hand, the air is clear for several yards between him and the mist, the shadow ought not to seem larger than life size unless he is really looking through a thin wreath of bright mist at a shaded and much more distant background.

I have carefully studied the instances quoted by Mr. Sharpe. Some are couched in language which is evidently designed with a view to picturesque effect rather than accurate description, but if allowance is made for this, and if also it is borne in mind that the shadow of a man cannot possibly be sharp at a distance of a mile or more, it will be seen that the conclusions I have drawn are supported by fact. I also append a letter from Mr. J. E. Walker,¹ of the Friends' School at Saffron Walden. He has twice witnessed the phenomenon. On one occasion he was in the fog, and his spectre seemed $1\frac{1}{2}$ times life size, but on the other he was in clear air and the cloud some distance away (he gives the distance as about one mile, which is probably too great), and in this case the shadow was about life size.

I have not entered upon the questions of bows and glories because my ex-

¹ "SPECTRES" IN THE ENGLISH LAKE DISTRICT.—Three gentlemen and myself witnessed this phenomenon on Blakefell on a July evening in 1873, under the following conditions:—

The summit of the mountain is about 2,000 ft. above sea-level, and no high hills obstruct the view between it and the Irish Sea to the west. In front lies a deep boggy valley. We had reached the top shortly after 8 p.m., and were soon interested in watching the formation of a white cloud in the boggy valley beneath. Slowly the bank moved round to the left until it reached a position behind ours at a distance of about one mile, and had very much the appearance of ordinary cumulus. As the sun neared the horizon our shadows became very clearly defined on the cloud. A hat thrown up was distinctly seen. In ten minutes the sun set and the spectres vanished.

Conditions, &c.

Place : Blakefell, Cumberland.

Time : At sunset in July.

Atmosphere : Clear, the day had been a hot one.

Size : Apparently not enlarged.

Position of Sun : Below us, so that the shadows were somewhat higher than the mountain.

Distance of Spectres : About 1 mile.

On another occasion, I cannot recall the year, I was passing over Low Fell, which lies between Loweswater Lake and Lorton Valley, at Christmas. The valleys were filled with dense fog, the top of Low Fell, 1,400 ft., being just clear. With a scanty amount of visible vapour between me and the sun, my shadow was thrown upon the more dense fog beyond, and appeared to be increased in size to about $1\frac{1}{2}$ times at a distance of 20 yds. It was of a very vapoury semi-transparent character, varying with the density or whiteness of the mist. The shadow was surrounded by a fog-bow, not showing prismatic colours, which formed an arch over the figure and then converged to my feet. These phenomena accompanied me for half an hour and for nearly a mile as I crossed the hill.

Conditions, &c.

Place : Low Fell.

Time : 10 a.m., mid-winter.

Atmosphere : Fogs of varying intensity, moving to and fro, with a clear gray blue above. Not frosty.

Size : Apparently $1\frac{1}{2}$ times larger than myself.

Position of Sun : About level with the top of the mountain.

JNO. E. WALKER,

periments were not satisfactory enough. Perhaps some other night the fog may be in a different condition and I may be able to study these also, but I am inclined to think that the lime-light is not brilliant enough to show coloured bands on an ordinary fog. Perhaps some one who has the command of a powerful electric light will put this matter to the test.

So far, however, as the shadows themselves are concerned it will now be easy for anyone to conjure up his own spectre, to be studied at leisure free from the glamour of magnificent surroundings.

DISCUSSION.

Mr. SHARPE said that he was gratified to find that Mr. Clayden had proved that the suggestion which he (Mr. Sharpe) had made in his paper on "Brooken Spectres," that the gigantic size was due to an error in judging distance, was correct. He could not quite agree with Mr. Clayden's explanation of the dark rays.

Mr. WHIPPLE said that when returning home from the Kew Observatory, on foggy nights, he sometimes carried a lighted taper to guide him across the Old Deer Park. It was necessary to hold this somewhat behind him, and he had often seen his spectre projected on the fog. In fact, he had so frequently observed it that he had never regarded it as a noteworthy phenomenon. The shadow usually appeared to be about half as big again as himself.

Mr. INWARDS remarked that there was a notable instance of error in judging the distance of the spectre in the letter from Mr. Walker, who estimated the distance of the shadow as one mile, but at the same time said he saw the shadow of his hat when he threw it up in the air.

Mr. SOUTHALL said that he once saw his spectre at the top of Snowdon, about a quarter of an hour before sunset: the shadow appeared to be very gigantic. Deception as to distance was very common on high mountains.

Mr. SYMONS said that Mr. Clayden appeared to have proved that the large sizes reported were due to error in judging distance, but the phenomena of the "glories" which were sometimes seen still required to be accounted for.

Mr. CLAYDEN, in reply, said that he had every reason to believe that his explanation of the dark rays was the true one. As Mr. Inwards had pointed out, Mr. Walker's statement was a notable instance of exaggeration in judging distance.

AN ACCOUNT OF THE "LESTE," OR HOT WIND OF MADEIRA.

BY H. COUPLAND TAYLOR, M.D., F.R.Met.Soc.

[Received March 16th.—Read May 20th, 1891.]

I HAD intended bringing before this Society, with their permission, a sketch of the climate of Madeira, but finding it would necessarily extend to too great a length; I am confining my present remarks to one of the most interesting phases of that climate, namely, to an account of the "Leste," or hot wind which is occasionally experienced in that island.

Being an invalid, I must beg for the indulgence of the Society for irregular times of observation and other defects the Fellows may discover in the following paper.

I must first state that my instruments are placed in a regulation Stevenson screen, and the blackened bulb *in vacuo* thermometer upon a post about 4 ft. from the ground. The maximum and minimum thermometers are by Casella, and duly tested at Kew, while the hygrometer (Mason's dry and wet bulbs) is by Negretti and Zambra. I also have had in use for some months a self-registering hair hygrometer by MM. Richard Frères of Paris, as likewise a thermograph by the same makers; but no very severe Leste has occurred since I had them.

This "Leste" is a very dry and parching wind and sometimes very hot, blowing over the island from the East-north-east or East-south-east, and corresponds to the Sirocco of Algeria or the hot North winds from the deserts of the interior experienced in Southern Australia, and locally known as "Brickfielders." It has been likened also to what is known in Italy and Sicily as the Sirocco, but notwithstanding that both winds have the same origin they differ materially; for this latter having become saturated with moisture in its passage over the Mediterranean, is, as a rule, damp and enervating, a great contrast to the Leste of Madeira, which, as I have before mentioned, is very dry. Occurring in such an equable climate, both as regards temperature and humidity, as that of Madeira, it possesses some special features of interest and no doubt attracts there a more general attention than it would do in some other more variable and extreme climates.

Its general characteristics were thus described by Dr. Heineken, who took careful observations in Madeira over 60 years ago, from the years 1826-1881, and the description fairly depicts its general character. He says:—"It reaches us immediately from the coast of Africa, after passing over 800 miles of sea; not a cloud is to be seen during its continuance, the whole atmosphere is of one uniform unvaried blue" (a rare occurrence in Madeira) "of a peculiar character, as though viewed through what a painter would term a thin warm aerial haze. It blows from the east and south-east, lasts almost invariably three days, and encounters you like the puffs from the mouth of an oven or furnace. . . . Birds and insects seem to suffer from it more or less,

. . . Furniture warps and cracks, books gape as they do when exposed to fire, and it is generally inconvenient and oppressive."

Mr. Yate Johnson, in his *Handbook to Madeira*, in the excellent chapter on its climate, adds :—" It usually begins as a gentle warm breath, afterwards there is more motion and sometimes the wind increases to a strong breeze.

. . . A thin haze extends over the land and gradually thickens out at sea until the horizon is completely hidden, and in that direction a low bank of grey cloud is seen in the east and south. In the earlier stages the Desertas are dimly perceived backed by a white cloud, but afterwards they become invisible." (The Desertas are a small group of islands only 10 or 12 miles distant.)

The special characteristics of this wind may now be described in more detail :—

It doubtless originates on the heated deserts of the Sahara, and is strictly analogous to the Sirocco of Algeria. As the air becomes heated it rises there in whirlwinds, carrying with it quantities of sand and dust to be borne along for hundreds of miles out to sea above the cooler North-east Trade current. It then gradually descends far out in the Atlantic, where it is experienced as a hot, dry, and often boisterous wind in Madeira and the Canary Islands, where it is called the " Levante." The reason why it does not become moist and enervating like the Sirocco of Palermo and parts of Italy by passing over the intervening sea is, I presume, due to its travelling at a much higher altitude in the former case, and thus it does not come into contact with the sea till it reaches the longitude of Madeira or thereabouts. But this wind is, no doubt, frequently modified before reaching Madeira, and so it may be asked what constitutes a Leste? and it is not always so easy to determine, as the indications of the slighter ones are not very pronounced, though those of a severe Leste are distinct enough. My opinion would be that there should be at least a difference of from 9° to 10°F. between the dry and wet bulbs, and this not merely at midday but at the morning and evening readings, and that this should be accompanied by a distinct rise in the temperature. Such a degree of dryness as these readings would indicate is never experienced in Madeira except when an Easterly wind is blowing.

Its occurrence is quite uncertain. Many months may elapse without its occurring, whilst, on the other hand, two or three of greater or lesser intensity may be felt within the course of a few weeks during the summer months. It is most frequent during the months of July, August, and September; it occasionally also visits the Island in various other months, but being modified by the cooler temperature prevailing, instead of being intensified by the heat of summer, it passes by almost unnoticed by the public. If, however, the weather at such times is carefully watched, the sudden accession of a greater degree of dryness and warmth is clearly due to this cause. For example, on February 19th and 20th, 1889, the maximum suddenly rose from 64° on February 18th to 76° on the 19th, and the minimum from 58° to 66°·5, the significance of which is unmistakable when it is remembered that the extreme minima for a week together frequently do not vary more

than 2° . Again, on looking at the relative humidity we find the indications equally plain, for on the 18th the relative humidity was 74% in the morning and 77% in the evening, whereas on the following day it had fallen to 42% and 87% respectively!

The duration of the Leste is generally stated to be three days, but it may last only one day, and, on the other hand, it may last up to six or seven; or, after lasting perhaps a day or two, it may seemingly disappear entirely for one day, only to recur on the day following, *e.g.* July 19th to 21st, 1890.

It is generally believed that the Leste is felt more severely at high elevations in the Island than in localities nearer the level of the sea, but this has been questioned; on the whole, however, the evidence seems to establish the popular belief, although simultaneous observations have not been taken to a sufficient extent to absolutely prove it. But there seems no doubt of the fact that the climate on the hills is affected first, *i.e.* before that on the lower levels. For instance, on June 6th, 1890, a Leste was reported from Camacha (2,800 ft.) which was not felt in Funchal till the following day. Again, in a Leste noted by Dr. Langerhaus in September 1888, the minimum on the first day at an elevation of 1,200 ft. was $68^{\circ}5$, whereas it was only 61° in Funchal. On July 10th, 1890, a Leste which was scarcely noticed at all in Funchal occurred at Camacha, when I registered a difference of more than 20° between the dry and wet bulbs, indicating a relative humidity of only 28% .

The force of this wind is often considerable, causing a rough sea with crested waves, and attaining a force of from 4 to 5 or even 6, on Beaufort's scale. During its onset it gradually supersedes, while during its subsidence it is again gradually superseded by, the North-east Trade wind, which is generally blowing steadily over the Island of Madeira during the season of the year when the Leste most frequently occurs.

As far as my observations go the barometer shows no certain or decided movement. As a rule it rises slightly at the commencement, though that is not invariably the case. The fall after the termination of the Leste is much more regular and decided than any rise that may have taken place at its onset.

The sky is perfectly cloudless except for a low and ill-defined bank of cloud to the east and south-east horizon.¹ There is, however, a decided haze both over land and sea as seen near sea level, which gradually obliterates the horizon and renders the Desertas invisible, though they are only about 10 miles distant and rise to the considerable elevation of 1,600 ft. This very marked haze, with such a dry wind and cloudless sky, is one of the most interesting features connected with the Leste, and many explanations of it have been offered. The usual one adopted has been that it is due to the particles of dust from the Sahara floating in the upper regions of the atmosphere; indeed, dust has

¹ A peculiar oval-shaped cloud to which Prof. Piazz Smith has called particular attention is sometimes seen from Funchal at these times, and is said to indicate a Leste blowing at a high elevation.

been deposited during violent Lestes in sufficient quantities to be collected by hand, but this very rarely happens. That there is at these times an abnormal quantity of dust in the atmosphere, even though it is quite impalpable, might be also inferred from the strictly analogous winds experienced near the Cape Verde Islands, where the amount of dust in the atmosphere causes what is known as the Red Fogs of those regions. Nevertheless, it is sometimes stated that the air during a Leste is "particularly free from dust." This statement may be so far true that there does not, as a rule, seem sufficient dust *per se* in the air to produce the haze which I myself noticed. For when staying at an elevation of 2,800 ft. during the summer of 1890, when three Lestes occurred, the atmosphere appeared peculiarly clear and luminous on every occasion; very different from the haze usually seen from Funchal. From the above considerations, however, the evidence seems to prove that there is an unusual amount of dust floating in the atmosphere. During a Leste in September 1890 I made an ascent to an elevation of 4,500 ft., and an observation I happened to make on that occasion may perhaps help to explain the nature of this haze. The haze on that day over sea and land was very marked, but the Desertas were just dimly visible. At an elevation of 2,800 ft. (Camacha) all the higher points around were, however, perfectly clear, and the atmosphere quite luminous and free from all haze. It was only on looking down to lower levels that the haze was apparent. Now, on making a further ascent to an elevation of about 3,500 ft., curiously, all the highest points of the mountains in the Desertas began to stand out perfectly clear and distinct, while the whole lower thousand feet or so were barely visible, causing a remarkable effect. The difficulty in accounting for the haze lies in the fact that we cannot suppose it is of the nature of an ordinary sea mist; for neither could the temperature of the sea bring the air in contact with it to anywhere near the dew point, nor is there known to be any counter-current of cool air during the height of the Leste either on land or sea to lower the temperature of the whole body of air to the point of precipitation. But now bearing in mind the extremely rapid evaporation which is going on from the sea under the existing conditions of temperature and humidity, secondly, the increased quantity of dust floating in the air at the time, and thirdly, the fact recently demonstrated by Mr. Aitken that a solid nucleus is always necessary for the condensation of watery vapour in the forms of fogs, mists, and clouds, may not the largely increased number of dust particles in the air have the power of attracting around themselves, and thus condensing some portion of the watery vapour arising from the sea in such large quantities and thus producing the haze, which the simple presence of impalpable dust in the air is not capable of doing? Thus while the haze is visible at the sea level and up to a certain altitude, at higher elevations, where the dry air still persists, the air remains clear and luminous.

We will now pass on to consider the conditions of temperature and humidity accompanying a Leste: The temperature rises considerably, but never reaches the intense heat experienced during the hot winds of Southern Australia or South Africa. The highest temperature reached is rarely much

above 90° , but this temperature being accompanied by a wind of considerable force and of great dryness, is decidedly felt both by the inhabitants and also by the vegetation of an island climate with such an equable temperature. The highest temperature I can find recorded is 98° . During a Leste lasting from July 26th to 29th, 1882, recorded by Dr. Langerhaus, the thermometer rose $90\cdot4^{\circ}$, and the highest minimum was $74\cdot5^{\circ}$. The minima are not as a rule so much higher than the average minimum as might have been expected with a continuance of the wind; a result due probably to the much less force with which it usually blows during the night, and to the rapid radiation taking place from the dryness of the air.

The relative humidity shows a marked variation from the mean, falling sometimes as low as from 20 to 25% . In the above-named Leste recorded by Dr. Langerhaus in 1882, the relative humidity was as low as 19% . It is remarkable how suddenly the change may take place. For instance, on July 9th, 1890, at 5 p.m., the dew was falling fast, the dry and wet bulbs standing respectively 61° and 59° , indicating a relative humidity of 88% , yet at 7.30 p.m. the dew had entirely disappeared and the relative humidity had fallen to 48% , there being 12° difference between the readings of the dry and wet bulbs.

The maximum reading in the sun by the blackened bulb *in vacuo* indicates during a Leste only a slightly higher temperature than on ordinary fine and clear days, though the heat of the sun feels very scorching, but the maximum solar intensity is usually less than on such a day; thus during a Leste in June 1890 at Funchal the shade maximum was 87° , the maximum in the sun 139° , and the maximum solar intensity therefore 52° ; while on a fine day, *e.g.* June 21st, with the considerable humidity of 71% , the shade maximum was $73\cdot5^{\circ}$, the sun maximum 184° , and the solar intensity $60\cdot5^{\circ}$. At an elevation of 2,300 ft. the same result obtained. On September 1st, with the difference of 18° between the dry and wet bulbs, or a relative humidity of only 84% , the solar intensity was only 52° , while on a clear day, with a relative humidity at noon of 72% , the solar intensity was 65° . Very similar results, though generally with slightly lower solar intensities, were obtained when the readings of the sun and shade temperatures were taken synchronously at noon, which is, perhaps, a more accurate method than taking the maximum of each for the day.

From these observations it would appear that the amount of moisture does not lessen the heat of the sun as much as would have been expected, or else on the occasion of the Leste the large amount of other suspended matter in the air interferes equally with it. The amount of ozone in the air is much diminished during a Leste. In a Leste of July 1890, during the three days of its most marked prevalence, the mean was 2.1 in a scale of 0—10, whereas on the six previous days it averaged 4.5, or more than twice as much. When the Leste has blown itself out it is almost invariably followed by rain or a thick mist, for as it is gradually replaced by the cooler North-east wind, which is the prevailing wind all the year round in Madeira (*vide* Dr. Buchan's *Report on Atmospheric Circulation—Challenger Expedition*), the temperature

falls, and the large amount of moisture absorbed into the air becomes condensed. This is well seen in the Leste which occurred in June 1890, and of which I append an account with others illustrating the foregoing statements.

TABLE I.

LESTE OBSERVED BY DR. LANGERHAUS AT AN ELEVATION OF 1,850 FT.

Date.	Temperature.		Relative Humidity.		
	Min.	Max.	9 a.m.	12 Noon.	9 p.m.
July 1882.			%	%	%
26th	65°6	83°8	70	73	47 ¹
27th	71°7	84°9	47	33	46
28th	74°4	90°5	19	23	66
29th	70°3	79°1	67	63	66

¹ Leste set in suddenly between noon and 9 p.m. on 26th.

TABLE II.

LESTE OF SHORT DURATION, NOT EXPERIENCED TO ANY EXTENT IN FUNCHAL, SHOWING
SUDDEN ONSET AFTER SUNSET.

Observations taken at Camacha at elevation of 2,300 ft.

July 9th, 1890.—Min. 46°5. Max. 72°5.

	Dry Bulb.	Wet Bulb.	Rel. Humid.	Dew Point.
			%	°
10 a.m.	69	62°2	65	56°7
5 p.m.	61	59	88	57°3
7.30 p.m. ...	59	47	43	36°3
9 p.m.	53	45	55	37

Grass, &c. wet with dew at 5 p.m., but all disappeared and quite dried up by 7.30 p.m. Cloudless day and Wind 0. Vane showing NE.

July 10th.—Min. 46°. Max. 77°5.

	Dry Bulb.	Wet Bulb.	Rel. Humid.	Dew Point.
			%	°
9 a.m.	74	55	31	41°1
12 Noon ..	75°6	55	28	40°4
5 p.m.	69°2	53°4	36	40°7
8 "	61	48	41	36°7

Wind E. Force 2. Clouds 0, except for undefined bank over Desertas. Mountains very clear.

July 11th.—Min. 54°5. Max. 74°.

	Dry Bulb.	Wet Bulb.	Rel. Humid.	Dew Point.
			%	°
10 a.m.	69°5	63°5	68	58°3
12 Noon	72	64	61	58
5 p.m.	66	62	78	58°8

Leste gone. Wind NNE. Slight drizzle in evening with clouds travelling from NE.

TABLE III.—LESTE OF JUNE 5TH–9TH, 1890.

Observations taken at Funchal at elevation of about 350 ft. A dense mist supervening on its subsidence.

Date.	Temperature.					Relative Humidity.			Clouds 0-10.	
	Min.	Max.	10 a.m.	5 p.m.	Max. in Sun.	10 a.m.	1 p.m.	5 p.m.	Mng.	Evng.
June 1890.						%	%	%		
5th	58.5	75	70	72	129	69	..	65	0	0
6th	64.5	84	80	79.8	136	39	41	48	0	0
7th	68	87	83.2	79	139	39	34	49	0	0
8th	64.8	76	73.4	72.2	130	72	..	78	1	0
9th	61.5	71	67	67.8	130	83	..	84	10	0

Date.	Ozone.		Wind.				Baro- meter.	Hours of Sunshine, Jordan's Recorder.		Solar Intensity.
			Direction.		Force.					
	Mng.	Evng.	Mng.	Evng.	Mng.	Evng.				
June 1890.							Ins.	h.	m.	°
5th	4	2	NE	NE	1	0	30.120	12	45	54
6th	3, 5	1	ENE	E	4, 5	2	30.171	12	35	52
7th	4	1	E	E	3	1	30.048	12	20	52
8th	3	1	E	E	1	0	30.075	12	25	54
9th	6	2	NW	.. ?	1	0	30.083	8	10	59

June 5th.—Leste reported from Camacha, but not affected this position yet. Splendid cloudless day. Mountains little hazy. Desertas indistinct. Fine sunset and red after glow.

„ 6th.—Leste set in during night. Very clear, with only slight haziness on land, more at sea. Rough sea. Desertas just visible, with some stratus lying over them. Wind falls to calm in evening, rising again at 10 p.m. to force 4 and 5.

„ 7th.—Leste continues. Hazy at sea, but Desertas visible. Slight undefined bank of clouds over them, clearing off midday. At sunset low lying bank completely hides their bases, while upper half of Islands remains clear.

„ 8th.—Leste diminishing. Very clear, except for low lying bank to SE. Horizon at sea hazy.

„ 9th.—Thick foggy morning, but clearing at 11 a.m.; remains misty over the sea. Very calm.

TABLE IV.—LESTE OF JULY 19TH AND 20TH, 1890.

Observations taken at Camacha at an elevation of 2,300 ft. A return of it on 22nd and 23rd, after subsidence on the 21st. A fall of 17° from morning of 20th to 21st.

Date.	Temperature.						Relative Humidity.			
	Min.	Max.	10 a.m.	12.	5 p.m.	7 p.m.	Blackened Bulb in vacuo.	10 a.m.	12.	5 p.m.
							Max. in Sun.			
July 1890.								%	%	%
18th	54.5	66	63	..	62.8	..	130.5	68	..	60
19th	52	83.5	74.8	82	73	71	141	45	33	38
20th	62	82.2	78.4	80.8	74	68	138	35	33	40
21st	54	71.5	61.8	67.2	66.2	60	133	68	68	50
22nd	56	77	73	..	71	..	136	42	..	40
23rd	63.5	78	76.6	..	70.6	..	136.5	49	..	67

¹ Barometer uncorrected for elevation or temperature.

TABLE IV.—Continued.

Date.	Clouds 0-10.		Wind.				Ozone.		Solar Intensity.	Hours of Sun.
			Direction.		Force.					
	10 a.m.	5 p.m.	10 a.m.	5 p.m.	10 a.m.	5 p.m.	Mng.	Evng.		
July 1890.										
18th	2	0	NE	NE	4	4, 2	7	2	64°5	h. m. 9 45
19th	0	0	ENE	E	2	3, 2	4.5	1	57°5	11 30
20th	0	0	E	E	2	3	2	1	56	11 10
21st	1	0	NNE	NE	3	3, 6	5	3	61°5	11 20
22nd	1	0	ENE	ENE	4	3	4	2	59	11 25
23rd	0	0	NE	..	1	0	3	1°5	57°5	11 20

July 18th.—Strong breeze all night, dull morning then clearing Desertas invisible, but air clear and no haze at this elevation, red glow at sunset.

„ 19th.—Distinct Leste. Hazy at sea. Desertas invisible all day. Very clear, except undefined bank of cloud to eastward.

„ 20th.—Low but dense bank of haze or mist to E and SE, otherwise very clear. Desertas invisible. Curious effect of mist rising from the sea like puffs of smoke which gradually dispersed as they rose in the air.

„ 21st.—Wind more Northerly. Fresh and cool. Desertas still invisible. Cloudless except for some cumulus over bank to SE. A fall of 17° at 10 a.m. from temperature of 20th. Wind rising to nearly gale force in evening.

„ 22nd.—A return of Leste.

„ 23rd.—Warm night. Splendid clear day. Wind backing to N. Leste passing off to hot summer weather. (?)

NOTE.—Minimum falling on 25th to 48°5' F. corresponding to its rise from 46°5' on 15th, 47°5' on 16th.

TABLE V.—LESTE OF FEBRUARY 17TH, 1891.

Date.	Temperature.						Relative Humidity.			Barom. cor. for Elevation and Temp.	Clouds 0-10.	
	Min.	Max.	10 a.m.	Noon.	5 p.m.	Max. in Sun.	10 a.m.	Noon.	5 p.m.		10 a.m.	5 p.m.
Feb. 1891.	°	°	°	°	°	°	%	%	%	Ina.		
15th	52	67°5	63°4	..	61	122	61	..	67	30°094	0	0
16th	51	69	64°4	68	62	124	50	54	58	30°124	1	1
17th	58°5	71°8	68	71	61°8	120	47	37	64	30°082	1	0
18th	51°8	67°5	62	..	61	120	68	..	62	30°086	1	1
19th	59	66°5	63	..	60°4	124	76	..	80	29°972	8	8

Date.	Wind.				Solar Intensity.	Hours of Sun.	Remarks.
	Direction.		Force.				
	10 a.m.	5 p.m.	10 a.m.	5 p.m.			
Feb. 1891.							
15th	NE	NE	2, 3	2	54°5	9°45	15th.—Cloudless day. Fresh NE breeze. Mountains very clear. Desertas rather hazy.
16th	ENE	ENE	2, 4	2	55	10	
17th	E	NE	2, 1	2	48	9°05	16th.—Desertas invisible and hazy at sea.
18th	E	E	3	2	52°5	9°35	
19th	SE	S	2	2	57°5	3°35	

REMARKS (continued).

16th.—Fresh Easterly wind with crystal waves at sea. 17th.—Desertas quite invisible. Very hazy at sea. Low undefined clouds to SE, topped by a few cumuli in morning. Wind falls to almost dead calm midday, when Relative Humidity is only

37 per cent. and sky very grey. No real blue to be seen. Cooler and damper wind from NE sets in at 4.30, and thermometer falls 4°. The Humidity increases 20 per cent., but at 7 p.m. the Relative Humidity had again fallen to 43 per cent. Sun set in thick haze. 18th.—Less hazy, and Desertas faintly visible. 19th.—Leste quite left us. Soft S wind. Large and heavy cumulus. Rain .80 in. during night.

TABLE VI.

LESTE OF FEBRUARY 19TH-21ST, 1889. A MARKED WINTER LESTE.

Date.	Temperature.				Rel. Humid.		Hours of Sun.	Barometer corrected. 9 a.m.	Ozone	
	Min.	Max.	10 a.m.	5 p.m.	10 a.m.	5 p.m.			a.m. 10	p.m. 5
February 1889.										
18th	58°	64°	62°	60°	%	%	Hours.	Ins.	3	..
19th	53	76	73.2	70.6	42	37	10.45	30.219	..	..
20th	66.5	75.5	75.4	68.8	41	47	10.45	30.216	05	2
21st	54.5	70	65.8	60.2	62	71	9.30	30.120	3	..
22nd	52.5	64	60.60	58	68	76	7	29.962	..	..

Date.	Clouds.		Wind.				Remarks.
	10 a.m.	5 p.m.	Direction.		Force.		
			Mg.	Ev.	Mg.	Ev.	
February 1889.							
18th	9	7	SE.	SE.	1	1	Hazy at sea.
19th	0	0	E.	E.	1	0	Cloudless but very hazy at sea.
20th	0	0	E.	E.	2	1	No clouds but bank of undefined clouds to SE.
21st	1	7	E.	..	1	0	
22nd	5	6	E.	ESE.	1	3	Cirro-cumulus.

On the 23rd rainfall .03, on 24th 1.27 inch.

DISCUSSION.

Inspector-General LAWSON said that he had had very little experience of the "Leste," although he well remembered that, between Madeira and the African coast, the vessel he was in was caught by a squall as this wind was setting in and narrowly escaped being capsized. He had had some experience of the Sirocco at Malta, which differed in character from the "Leste." In Natal, too, a North-east wind was sometimes experienced which bore a very close resemblance to the Maltese Sirocco. During summer a South-westerly wind, of high temperature, with a very low dew point and clear weather, is occasionally met with at Malta, and more frequently over Sicily and the south-west coast of Italy, which is described by writers as the Sirocco: but at Malta, the wind so denominated comes from the South-east later in the season, is rather cooler than the mean temperature of the season, with cloudy hazy weather, so that the horizon is often invisible, and moisture is deposited copiously on all exposed surfaces. Meat putrefies rapidly during the prevalence of the latter wind, and wine bottled during it does not clear. It is obviously derived from the Indian Ocean, while the Sicilian Sirocco comes from the African desert. At Natal, during January and February, a wind from the North-east is frequent, presenting the characters of the Malta Sirocco, there being cloudy hazy weather, with much moisture in the atmosphere.

Dr. BARNES said that he should much like to know what effect the "Leste" produced upon the health of the residents at Madeira.

Mr. SYMONS said that it would be of considerable interest to know whether,

when the "Leste" prevailed and the atmosphere was so full of dust, any twilight effects, such as those seen after the Krakatoa eruption, were observed; of course the sand particles were very different from those of pumice.

Inspector-General LAWSON said that at Sierra Leone the brown dust brought by the wind from the desert never attained a greater altitude than 700 or 800 ft. above sea-level, so that it was not sufficiently high to cause any sunset effects.

Mr. TRIPP said that differences of 9° and 10° between the dry and wet bulbs did not indicate such dryness as might be expected from a wind originating in the Sahara, and he supposed this was owing to its having passed over some 800 miles of sea. In other countries dry winds came from the direction of the greatest heated surface of land, and their direction varied accordingly. In British Kaffraria, Cape of Good Hope, he had noticed the dry bulb at 100° and the wet at 75° , this indicating a relative humidity about 28 %. This was in the afternoon at about 5.30. His observations were taken principally in the morning about 9 a.m., and he had then repeatedly seen differences of over 20° , indicating a relative humidity of 80% or over. He had, however, never noticed anything equal to Dr. Langerhaus' observation of 19%. He had not, however, searched for this phenomenon, and had systematic observations been made in this direction perhaps greater degrees of dryness than those he had noticed might have been discovered. With regard to duration, the most decided instance he had seen had been a succession of four mornings with a relative humidity ranging from 81 to 53, and giving an average of under 44%. These hot winds were much felt by vegetation, and were often succeeded by dust and rain storms with thunder and lightning; they generally came from the North-west.

The PRESIDENT (Mr. LATHAM) said that the sunset afterglows which he had seen in Egypt were magnificent, but whether they were due to the presence of dust in the atmosphere or not he was unable to say. At Bombay, too, the sunsets were very beautiful, but inland and in the neighbourhood of the Himalayas such sunsets were never seen.

A CURIOUS CASE OF DAMAGE BY LIGHTNING.

By ALFRED HANDS, F.R.Met.Soc.

(Plate VII.)

[Received May 20th.—Read June 17th, 1891.]

ON the afternoon of Sunday, April 5th, 1891, a severe thunderstorm passed over South Staffordshire, and during Divine Service Christchurch, commonly called the Forest Church, Needwood, was struck by lightning, and some slight damage was done.

I received instructions to examine and test the lightning conductor and report as to the cause of the accident. On examination I found the damage, although only of a trifling character, possessed some points of both an uncommon and instructive character, and I thought therefore that a description might be of interest to the Fellows of this Society.

The church, which is a small building having a tower at the western end, stands on high ground, and has several trees round it. I have prepared drawings which will serve to illustrate the church and the nature of the damage which was done. (Plate VII.) No. 1 is the south elevation; No. 2

is the eastern end, while No. 3 is a ground plan of the building. Nos. 4 and 5 show details which I shall explain later on.

The tower, which has four pinnacles, each surmounted by a small wrought iron vane, is about 64 ft. in height, while the ridge of the roof is 84 ft. from the ground line. The length of the building without the tower is 60 ft.

The conductors, which had been erected, I believe, about seven years before, consisted of a main down conductor of copper tape 2 ins. by $\frac{1}{8}$ in. carried from the south-east pinnacle to earth, while each of the other pinnacles had a branch conductor of copper tape 1 in. by $\frac{3}{8}$ in. carried to the main down conductor. All these conductors were connected to the vane rods by copper bands made in two halves fastened by copper bolts and nuts, and to these bands the tapes were secured by copper rivets. The earth connection was made by a copper-plate 3 ft. by 3 ft. by $\frac{1}{8}$ in. in accordance with the instructions formulated by the "Lightning Rod Conference."

Unfortunately no one saw the lightning strike the church, the only person in the neighbourhood outside the building at the time being a man who had taken shelter from the rain under a yew tree some twelve or fifteen feet from the conductor, and he was so placed that he could only see the lower part of the building. We must therefore take our ideas of what occurred by deduction from the traces the discharge left in its course.

The main conductor at its junction to the vane (*a* Fig. 1) was disconnected, the copper bolts fixing the band or collar and also the copper rivets which connected the tape to the band being broken, but there were no marks of fusion. Further down (*b*. Fig. 1) a spark passed between the conductor and the lead flashing, which runs along the edges of the slates about 2 ft. away, damaging the stone parapet in its course. Lower down (*c*. Fig. 1), a few inches from the ground, a spark passed through the wall into the building. Along the ridge of the roof sheet lead is laid in lengths overlapping one another, and this lead was turned up at every alternate joint. The rain-water gutters along the southern side were broken and thrown down in two places, and the rain-fall pipe at one side of the end of the building (*d*. Fig. 2) was broken at the joints and also thrown down. The corresponding fall pipe on the other side had slight damage at the joints.

The most curious part of the damage, and one which appears to me inexplicable, was on the top of the tower. As usual with such places, it is covered with lead, which was in connection with the lightning conductor. Round each of the four pinnacles there is an iron band with a stay rod of $1\frac{1}{2}$ in. iron from it to the lead flat, where it is secured by a $\frac{3}{4}$ in. iron bolt. The lead is $\frac{1}{8}$ in. in thickness: beneath that there is 1 in. floor boarding, then there is a space of 8 ins., and below that there is a 9 in. rafter through which the bolt rod passes. Just under this stay rod there was a hole about an inch in diameter, made as if it had been punched, the edges of the lead being turned downwards and the wood floor board splintered.

No further damage was done here, but the buttress at the south-east corner of the building (*e*. Fig. 2) was broken through by a discharge which took place between the fall-pipe and the railings on the south side of the church,

and further on (*f.* Fig. 1), where the metal continuity of the railings was broken by a gate being open, a discharge passed through the brick step slightly disarranging it.

On the opposite side of the building there are also railings, and discharges passed from these to earth in three places, cutting channels through the grass somewhat as shown in Fig. 5.

As previously mentioned, a spark passed into the church at the base of the conductor, and, of course, I at once suspected that there was metal behind there; but I may mention as an instance of how people who do not understand the subject may overlook important details, that I was assured that there was no metal whatever. On examination, however, I found that just inside the wall, which is 18 ins. in thickness and therefore within about 2 ft. of the conductor, there was fibre matting the ends of which lying against the wall were bound with lead, about equal in quantity to a 1 in. diameter pipe flattened out. There were two lengths of this binding placed end to end, then there was a break of 4 ft. 11 ins., when the binding commenced again and continued past the centre, where there is a step between the tower and the body of the church.

Just at the corner where the spark passed (*c.* Fig. 1), close to the wall and on the lead was a hassock through which the spark tore its way, driving it 40 ft. up the church; then the discharge was conducted by the two lengths of lead binding to where the break occurred. There was a wooden seat which was the next best conductor available, and the discharge passed through the lower part of it, moving it by the impact of the blow 22 ins. out from its position. Further on, where the lead bindings commenced again, it left the seat and was conducted to the step, where it struck through the stone to a large iron furnace formerly used for heating the church. This furnace is approximately 8 ft. high, 2 ft. 6 ins. deep, and 2 ft. 6 ins. wide, and is about an inch in thickness.

As I have said the whole of the damage was of a trifling character, the hole through the wall being merely large enough to allow of one finger being inserted, and the damage to the step being about the same.

On testing the lightning conductor, I found the connections between the tapes and the vane rods had become bad owing to oxidation, the resistance in one case being over 2,000 ohms. The resistance of the earth connection was 14 ohms.

As regards this resistance to earth, I may say that it is still an undecided question as to what should be the maximum resistance allowable in the earth connection of a lightning conductor. From my experience in testing, I am of opinion that for every five that would be found to have a lower resistance than this, 95 would be found to be higher. It may sound high to electricians who have to deal with electricity at low tension, but for high potential, such as a discharge of lightning, it would form comparatively no obstruction. It is such a resistance as would under ordinary circumstances be given by a copper-plate 8 ft. square bedded in coke. Under very favourable circumstances, that is in a very damp locality, I have found that a copper-plate this

size laid 2 ft. under ground has given a resistance of a fraction of an ohm merely, while in a light porous soil I have known a plate 10 ft. by 8 ft. 6 ins. at a depth of 10 ft. show a resistance of 80 ohms.

Undoubtedly a resistance of half an ohm is better than two ohms, but in a case such as this where there are no gas or water pipes, or other metals having a low resistance to earth, such a small resistance as 14 ohms cannot be considered sufficient to explain a flash passing from the conductor to other metals.

If it was absolutely necessary for the "earth" to be below 14 ohms, then at least 95 per cent. of the conductors in England would have to be condemned as inefficient. Personally, I think that the question of the maximum resistance allowable depends upon what other paths to earth are available. For instance, a plain stone structure without a particle of conducting matter in its composition besides the lightning conductor would be protected by a comparatively high resistance; while one with gas and water pipes, which necessarily have admirable earth connections, should have a conductor with a nominal resistance only.

I have for a long time considered that it is possible that where a conductor is carried close to metals either inside or outside a building, that a spark may pass no matter how low the resistance to earth, indeed it is obvious that the "Lightning Rod Conference" took this possibility into account when they recommended that all metals in the neighbourhood of the conductor should be brought into metallic contact with it. Great care, therefore, should be taken by those fixing conductors to see that they are not placed near any other metals, either inside or outside the buildings, which it may not be convenient or expedient to connect them to, and the owners of the buildings should take care that no metals are placed in the neighbourhood of the conductors after they are fixed.

In the present case there was in the vault under the tower a large mass of iron. This would have been perfectly safe, but that a line of metal had been recently laid from close to this furnace to within about 2 ft. of the conductor, and this was equivalent to reducing the distance between the furnace and the conductor very considerably.

At the time that the conductor received the discharge of lightning, the copper tape and the metals inside the church would owing to inductive action be in oppositely electrified states, and consequently a spark would pass to restore the equilibrium.

It is extremely difficult to say what exactly was the nature of the discharge at Needwood Church, but I am convinced by several details that it was exceptionally severe. There are circumstances pointing strongly to an upward discharge of lightning, but this is not fully borne out; while the remark of the man I have referred to that he saw a large ball of fire come down the tower, might lead us to imagine that the phenomena might be connected with "globular" lightning.

After a careful examination of the building I am inclined to think that it was either struck by two flashes simultaneously, or by a discharge which

bifurcated, part falling on the south-east pinnacle of the tower, and part on the ridge of the roof. The first part was conducted down the copper tape to earth, but a spark passed through the wall to the binding of the matting, as I have already described. The other part divided, part passed along the lead on the roof and sparked across the parapet to get to the conductor, the remainder going to earth by the rain water gutters and fall pipes; but it is evident that nearly all passed down on the south, and very little on the north side. It was raining heavily at the time, and no doubt water had penetrated under the lead at the joints along the ridge, so that the heat generated by the resistance at the joints might turn the water into steam and so blow up the edges by the force of the explosion.

The damage to the rain water pipes and gutters would probably occur in a slightly different way. This kind of damage takes place in nearly every case where rain pipes act either as conductors or auxiliary conductors to a flash of lightning, and I have heard several explanations, but none that seem quite feasible. It should be borne in mind that the gutters and pipes are badly put together, no attempt being made to make the joints electrically good, in fact there is an enormous resistance in some of them almost from the moment they are put up. There is sure though to be one point in each of the joints where the resistance is less than in the rest of the joint, and an electric discharge in passing from one length of pipe or gutter to the next, chooses this path of least resistance and passes across in the form of a spark, so generating heat at this point, and this heat is so great and is generated in such an inconceivably short space of time, that before it can be conducted along the metal, expansion takes place at one part, which, as the metal is brittle, causes the iron to crack and the piece broken off springs away to a distance. I have often tried to find one of the pieces to look for marks of fusion, but have never been successful as they are probably projected to too great a distance. In this case I found one piece of gutter which, although it was not broken, shows signs of fusion such as I expected.

The discharge that took place at the back of the church between the rain-fall pipe and the iron railings is, I think, explicable in precisely the same way as the spark which passed between the conductor and the furnace inside the tower. In this case the rain-fall pipe was acting as a lightning conductor, but with a bad earth connection, the resistance to earth being over 1,100 ohms.

In each of these cases of side flash I consider it is as correct to say that sparks passed from the isolated masses of metal to the conductors, as it is to say that they passed the other way, indeed in the case of the last named discharge the injury to the rain-fall pipe (if really caused by lightning) seems to prove that the discharge was from the railings, and was therefore entirely an induced discharge and did not exactly form part of the lightning flash.

On the other side, it is to be remarked that the railings, although precisely the same distance from the fall pipe on that side, did not receive a spark from the pipe. Hence the charge that passed down this side must have

been much less than that on the south side. As may be expected, the earth connection of this fall pipe was even worse than the other.

There would, however, still be the induced charge in these railings to be got rid of, and consequently on this charge being liberated, it would go direct to earth, cutting the curious furrows in the grass which I have described. I take the intensity of this induced charge to be a proof of the exceptional violence of the inducing charge.

The lightning conductor could not be passed as in a satisfactory condition, owing to the bad joints at the connections to the vanes. Besides this, there were some bad bends, the tape being carried down from the pinnacle to the lead flat and then up again over the parapet. Again, the conductor ought to have been connected to the lead flashing on the roof where it was carried near it.

I contend, however, that none of these faults were sufficient to account for the spark that passed at *c*. Fig. 1, and that the sole cause of the discharge there was the lead bound matting having been laid so close to the conductor.

Although the accident to Noedwood Church may be considered to be a case of the partial failure of a lightning conductor, it must be borne in mind that it carried off the bulk of a discharge which, had there been no conductor, would have probably wrecked the tower and caused serious loss of life by the masonry falling through the roof upon the congregation. As it was, the whole of the damage would be set right by the expenditure of a few pounds, and would be covered by the insurance policy.

As regards the body of the church, we may consider that it was never protected from lightning. No expert would say that a conductor on the tower, however perfect, would afford absolute protection to the other end of the church. As a rule, however, those having the management of such buildings prefer to protect the tower or spire, which is the part most likely to be struck, and leave the rest to chance, owing to the extra cost which would be entailed by completely protecting the whole building.

Of course, where there are rain water pipes and gutters on the building, a discharge of lightning must divide itself between them and the conductor in proportion to their respective capacities; and therefore, unless the joints were made electrically good, or continuous conductors were carried along them in order to bridge the points of resistance, there is always a danger of some of them being broken. Such very slight damage as this, however, need scarcely be considered, I think, when we take into account the dreadful havoc and ruin which lightning conductors, properly applied and fitted, will prevent.

DISCUSSION.

Mr. SYMONS said that a case of damage by lightning bearing a very close resemblance to that which had been so thoroughly discussed by Mr. HANDS, was to be found in the *Report of the Lightning Rod Conference* (p. 217). In that instance Carmarthen Church, which was provided with a conductor, was damaged by lightning, and the disruptive discharges which caused the damage were due to

the conductor being placed in close proximity to a gas main, but not connected with it, the lightning in its passage down the conductor naturally glanced off to the gas-pipe because it formed a good earth. The conductor, however, as in the case described by Mr. Hands, doubtless saved the church from very serious damage. It was one of the recommendations of the Lightning Rod Conference that all the metal work in a building should be in perfect connection with the lightning conductor. In erecting a lightning conductor it was absolutely necessary that every part of the work should be thoroughly well done. He agreed with Mr. Hands that the present case was not an instance of the occurrence of ball lightning, and that the east end of the church was not in the area of protection afforded by the lightning conductor.

Prof. MASCART remarked that the resistance of 14 ohms was far too great, and that it was desirable to utilise gas and water mains in forming the earth connection for lightning conductors. In France it was now the common practice to substitute a long tube buried in the earth for the small plate, usually employed in England, as the earth connection. The lightning conductors fixed on the Eiffel Tower were provided with tubes 100 metres long, buried so deeply in the soil that they were always damp.

Mr. ELLIS said that this paper formed an excellent object lesson to himself, as he was now concerned in putting a new lightning conductor to the parish church at Greenwich, and had received valuable information from Mr. Hands' clear account of the damage done to the church at Needwood. It was a comforting thing to find that even an imperfect conductor might, to a great extent, do its duty. The old conductor on Greenwich Church had been carefully examined, the connections and joints were found to be in a bad condition, and the conductor was about to be entirely renewed.

Mr. DINES drew attention to the case of a well-known abbey in England where the end of the lightning conductor was immersed in water in a sealed iron tube buried in the ground.

Mr. STANLEY said that in tropical countries iron rods about 1½ in. in diameter were preferred to copper band lightning conductors. The terminals were pointed brass rods, tipped with platinum. He did not know which metal formed the best conductor under the conditions, but iron was probably cheaper. In the case of damage described by Mr. Hands it seemed that the electrical discharge was too great for the conductor to efficiently carry it off.

Mr. SYMONS said that he was not prepared to discuss the relative merits of iron and copper as lightning conductors, but doubtless the reason that copper was not used in the countries referred to by Mr. Stanley was because, being of greater value than iron, it was much more likely to be stolen. An iron conductor afforded for the same outlay a larger surface than a copper one, but in a damp atmosphere like that of the British Isles iron rapidly rusted and soon spoiled.

The PRESIDENT (Mr. Baldwin Latham) said that in India iron was almost universally used for lightning conductors, chiefly because the natives stole copper. He much preferred a strip of copper to a rod of iron. In the case of tall chimney shafts a lightning conductor did not give an immunity from lightning stroke, and considering the large amount of iron, such as boilers and furnaces, which was usually to be found in large works, and generally unconnected with the conductor, he was surprised that cases of damage from lightning were not much more frequent.

Mr. HANDS, in reply, said that he thought it would not be possible to connect all metal work inside and outside a building with the lightning conductor. The better way would be to examine the interior of a building first, to ascertain the amount and position of the metal work, and then arrange that the conductor should be placed at a sufficient distance from such metallic substances. He could not agree with Prof. Mascart that the resistance of the earth connection should be less than one ohm, as in districts with a naturally dry soil the cost of carrying the conductor to a sufficient depth to obtain such a resistance would be greater than anybody would care to incur.

On the Mean Temperature of the Air at the Royal Observatory, Greenwich,
as deduced from the Photographic Records for the Forty Years from
1849 to 1888.

By WILLIAM ELLIS, F.R.A.S.

[Received May 11th.—Read June 17th, 1891.]

THE main object of the present paper is to communicate to the Royal Meteorological Society a table of mean monthly temperatures deduced from the Greenwich photographic records, but it has appeared to me that it might be desirable and useful to include also some account of the way in which at different times Greenwich mean temperatures have been formed.

On the establishment of the Magnetical and Meteorological Department of the Royal Observatory, Greenwich, in the year 1840, eye observations of air temperature were made every two hours, commencing in November of that year, until the year 1847, excepting on Sundays and some other days, when a few observations only were taken. In 1848 observations were made six times daily, but fewer on Sundays, and since 1849 usually four times daily. The continuous photographic record is available since 1849. Readings of self-registering maximum and minimum thermometers have been taken throughout.

The mean daily temperatures given in the Greenwich volumes until the end of the year 1847 depend upon the twelve two hourly eye observations of each day, there being during this period no Sunday results. In 1848 they were deduced from the six eye observations only, corrected for diurnal inequality, and from 1849 to 1876 from the four eye observations, corrected for diurnal inequality, combined with the mean of the readings of the self-registering maximum and minimum thermometers, corrected for the excess of such mean above the true mean, these various corrections being determined and applied in the manner indicated by Mr. Glaisher in his paper in the *Philosophical Transactions* for 1848.¹ Commencing with the year 1848 the fewer observations of Sunday have been utilised to form values for that day. The mean daily temperatures contained in the Meteorological Report communicated to the Registrar General, for publication in his *Weekly Return of Births and Deaths in London*, are, up to the year 1876, the same as those that appear in the Greenwich volumes. In the year 1877, at my suggestion, a change was made, the mean daily temperatures given in the Greenwich volume having been since that year deduced from the photographic records alone, each daily value being the mean of 24 hourly values taken from the photographic register, and reduced to the reading of the dry bulb thermo-

¹ On the Corrections to be applied to the Monthly Means of Meteorological Observations taken at any hour, to convert them into Mean Monthly Values.

meter of the revolving stand. In the case of accidental failures of register, which during this period were not numerous, eye observation values were employed in order that the whole period should be completely represented. But for the report supplied to the Registrar General values deduced entirely from the eye observations had to be as before employed, since it was not possible to deal with the photographs in the limited time available, at the end of each week, for preparation of the weekly report which has to be completed on Monday morning for the week ending the previous Saturday at midnight. Commencing, however, with the year 1878, new corrections for diurnal inequality and for the excess of the mean of the maximum and minimum thermometer readings above the true mean were determined from the Greenwich twenty years' meteorological reductions,¹ varying the corrections through each month as necessary, instead of using one set of corrections through the month. The corrections for diurnal inequality are to be found in the twenty years' reductions, but the new corrections to the mean of the maximum and minimum, to reduce it to the true mean as deduced from 24 hourly values, have never been published. It is proposed to add them at the end of this paper.

The twenty years' reductions contain a discussion of the photographic records of air temperature from 1849 to 1868. As there published, the monthly means (Table 52) are not corrected for the effect produced by the omission of days on which there were no available registers, and which were more numerous during this period than in later years. These means I some years ago corrected for my own use by including for omitted days values derived from the eye observations, but the corrected values were never published. More recently the photographic records for the years 1869 to 1876 have been also discussed, and the results, duly corrected for the effect of omitted days, in this period few in number, have been included in an appendix to the Greenwich volume for 1887, thus completing the reduction of the photographic records from 1849 to the present time, since beginning with 1877, as before-mentioned, the mean daily temperatures given in the annual volume are those deduced from the photographs, which are in all cases reduced to the reading of the dry bulb thermometer of the revolving stand.

It is now therefore possible to form a table of monthly means of Greenwich temperatures beginning with 1849, depending essentially on the photographs, and completely representing the period, since eye observation values have been throughout included for omitted days, which, more numerous in earlier years, were comparatively rare in later times.

It is proposed to undertake shortly at the Royal Observatory the preparation of tables of meteorological averages, to include amongst other things averages of meteorological elements for days of the year. The work has, indeed, been commenced, although no very great progress has been yet made with it owing to the pressure of other work which has to be first cleared off.

¹ *Reduction of twenty years' Photographic Records of the Barometer and Dry-bulb and Wet-bulb Thermometers, &c., made at the Royal Observatory, Greenwich.*

But as reference is frequently made to Greenwich air temperatures, it has occurred to me that, as the monthly means already exist, scattered, however, through many volumes, it might be useful to meteorologists at once to collect them into one table for immediate publication. The results from 1841 to 1847, depending on two-hourly eye observations, could not be here included, it being a part of the scheme just spoken of to complete the daily series for that period by forming values for Sundays; and as the year 1848, if included, would depend also on eye observations, I have preferred to give here the values commencing only with 1849, the beginning of the available photographic record. One portion is, indeed, new; the monthly means 1849 to 1868, as corrected for omitted days, not having been before published.

It may be useful here to indicate the changes that from time to time have been made in the position of the revolving stand, on which the thermometers for eye observation are placed, and to the dry bulb thermometer of which the photographic indications are reduced. It was first brought into use in March of the year 1841 (the observations for the few previous months having been made with the thermometer suspended in a temporary manner), and was originally set up in the north-east re-entering angle of the Magnetic Observatory, about 6 ft. from the walls of the building; in July of the year 1846 it was moved to a position 28 ft. south of the southern arm of the Magnetic Observatory, and in 1868 was shifted to a position 12 ft. further south. In the summer of the year 1878 some minor repairs and alterations of the stand were made, and in September of the same year a horizontal circular board 8 ft. in diameter was fixed to the post carrying the thermometer frame, in a position below the frame, at a height of 2 ft. 6 in. above the ground.

It will be seen by the accompanying table that the mean annual temperature deviates from the general mean of the 40 years, by more than 1° in excess, in nine of the years of the series, the only deviation above 2° being $+2^{\circ}5$ in 1868, a memorable year, in which, in more than half of the months of the year, the temperature was considerably above the average. The annual temperature deviates from the general mean more than 1° in defect, in six of the years, the deviations above 2° being $-2^{\circ}3$, $-2^{\circ}0$, and $-8^{\circ}2$ in 1855, 1860, and 1879 respectively, due in 1855 mostly to the extreme cold of the early part of the year, in 1860 to the remarkably cold summer, and in 1879 to extreme cold in spring and early summer and at the beginning and end of the year. The mean annual departure from the average, irrespective of sign, is $0^{\circ}88$. The preponderance of cold in the last 10 years, 1879 to 1888, I have before pointed out:¹ only in two years out of the ten is the annual temperature above the general average: a long sustained depression, to be followed, no doubt, in due course by a series of warm years, although the two following years 1889 and 1890 have proved to be also cold years. It would be of great interest to make out whether the effect is a local one, and if so to what extent, and whether this part of the world only has suffered in this way.

¹ On the Variation of the Temperature of the Air in England during the period 1849 to 1888. *Quarterly Journal Royal Meteorological Society*, Vol. XV. p. 228

MONTHLY MEAN TEMPERATURE OF THE AIR AT THE ROYAL OBSERVATORY, GREENWICH, AS DEDUCED FROM THE PHOTOGRAPHIC RECORDS, 1849-1888.

The means depend on 24 daily values, reduced to the reading of the dry bulb thermometer of the revolving stand. No correction has been applied for elevation, 160 feet above sea level.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly Mean.	Excess above Average.
1849	40.8	43.1	42.9	44.5	54.8	59.4	62.2	62.7	58.5	51.3	44.1	39.2	50.3	+0.8
1850	34.1	44.5	39.9	49.3	51.6	61.2	62.2	60.8	56.2	46.7	46.4	40.4	49.4	-0.1
1851	43.0	40.0	42.7	45.5	51.7	59.7	60.3	62.6	56.2	52.5	37.7	40.6	49.4	-0.1
1852	41.9	40.7	40.6	45.4	52.1	56.9	67.0	62.3	56.8	47.8	49.0	47.6	50.7	+1.2
1853	42.6	33.2	38.2	46.0	52.5	59.0	61.0	60.1	55.4	51.3	42.2	34.0	48.0	-1.5
1854	39.3	39.4	43.6	48.6	51.2	56.5	61.0	61.1	57.9	49.5	40.6	41.2	49.2	-0.3
1855	34.9	29.2	37.8	45.9	49.3	57.7	62.6	62.4	57.3	51.5	41.6	36.2	47.2	-2.3
1856	39.2	42.1	39.2	47.5	49.9	59.7	61.6	63.7	55.2	52.0	41.0	40.2	49.3	-0.2
1857	36.8	38.9	41.9	46.3	54.3	62.5	65.1	65.7	59.9	53.2	46.0	45.1	51.3	+1.8
1858	37.6	34.9	41.5	46.8	52.2	65.7	61.4	62.3	60.4	51.2	39.5	41.1	49.6	+0.1
1859	40.5	43.4	46.8	47.5	53.5	62.3	68.9	63.9	57.0	51.4	42.1	36.7	51.2	+1.7
1860	40.0	35.7	41.5	43.3	54.6	55.7	58.3	58.2	53.7	51.2	41.0	36.4	47.5	-2.0
1861	34.0	42.2	44.1	44.9	52.7	59.9	61.5	63.5	57.3	55.2	41.0	41.0	49.8	+0.3
1862	39.3	41.3	43.3	49.2	55.9	57.1	59.6	59.6	57.7	52.5	39.8	43.7	49.9	+0.4
1863	42.2	42.2	43.9	49.6	52.3	58.8	61.4	62.3	53.9	51.9	45.9	43.6	50.7	+1.2
1864	36.6	36.0	41.5	48.8	54.6	58.3	62.3	60.2	57.1	50.9	42.3	38.6	48.9	-0.6
1865	36.5	37.0	36.7	52.9	56.9	61.7	64.6	60.4	63.8	51.3	45.2	42.9	50.8	+1.3
1866	43.1	40.9	40.8	48.6	50.8	61.8	61.9	59.7	56.6	51.6	44.7	43.1	50.3	+0.8
1867	34.6	45.1	38.0	49.9	54.0	59.2	60.1	62.5	57.8	49.1	41.5	37.7	49.1	-0.4
1868	37.6	43.5	44.5	48.7	58.0	63.2	68.1	63.9	60.4	48.2	41.8	46.1	52.0	+2.5
1869	41.4	45.6	37.9	50.9	51.1	56.2	64.8	60.9	59.1	49.3	43.4	37.9	49.9	+0.4
1870	38.5	36.3	40.1	49.2	54.1	62.2	66.0	61.3	56.0	50.4	41.8	33.7	49.1	-0.4
1871	33.4	42.6	45.0	48.2	52.4	55.5	62.0	64.9	57.7	49.6	37.4	38.4	48.9	-0.6
1872	41.5	44.8	44.7	48.8	51.5	60.0	65.5	60.9	57.7	48.3	45.5	42.9	51.0	+1.5
1873	42.3	34.7	42.1	46.3	51.2	59.4	64.0	62.9	54.9	48.3	44.5	40.7	49.3	-0.2
1874	41.9	39.0	44.1	50.5	51.0	58.8	64.9	60.8	58.2	52.2	42.2	33.3	49.7	+0.2
1875	43.6	35.5	40.9	47.0	55.6	60.0	59.9	63.6	60.8	49.3	42.7	38.6	49.8	+0.3
1876	37.3	41.3	41.6	48.0	50.1	59.6	66.7	64.2	56.3	53.6	44.2	44.2	50.6	+1.1
1877	42.9	44.0	41.0	46.1	49.4	62.3	61.5	62.2	53.3	49.4	46.0	41.0	49.9	+0.4
1878	40.4	42.3	42.3	48.0	55.1	60.2	63.2	62.5	56.9	51.5	39.8	33.7	49.7	+0.2
1879	31.8	38.3	41.2	43.5	48.6	57.0	58.2	60.2	56.3	49.3	38.5	32.5	46.3	-3.2
1880	33.3	42.1	44.2	47.2	52.6	57.5	61.6	62.8	59.7	46.4	42.8	43.3	49.5	0.0
1881	31.7	38.0	42.6	45.8	54.0	58.6	65.5	59.2	55.7	45.4	49.0	39.9	48.8	-0.7
1882	40.5	42.0	46.2	48.0	54.5	56.7	60.3	59.9	54.6	51.0	43.8	40.2	49.8	+0.3
1883	41.4	42.9	36.3	47.0	53.1	58.9	59.8	62.2	56.9	50.7	43.7	40.5	49.4	-0.1
1884	43.9	42.1	44.4	45.3	54.2	58.1	63.2	65.1	59.4	49.2	42.6	41.2	50.7	+1.2
1885	36.6	43.9	40.3	47.6	49.8	59.6	63.6	58.6	55.4	46.5	43.5	39.0	48.7	-0.8
1886	36.3	33.7	39.8	46.6	53.3	57.7	63.1	62.3	59.1	53.3	44.4	36.6	48.8	-0.7
1887	35.8	38.9	37.9	44.2	50.1	61.0	66.5	62.5	54.4	45.2	40.8	38.0	47.9	-1.6
1888	37.9	35.3	38.3	43.5	53.0	58.3	58.0	59.2	55.9	46.0	47.2	40.8	47.8	-1.7
Means 1849-1858	39.0	38.6	40.8	46.6	52.0	59.8	62.4	62.4	57.4	50.7	42.8	40.6	49.4	-0.1
Means 1859-1868	38.4	40.7	42.1	48.3	54.3	59.8	62.7	61.4	57.5	51.3	42.5	41.0	50.0	+0.5
Means 1869-1878	40.3	40.6	42.0	48.3	52.2	59.4	63.8	62.4	57.1	50.2	42.7	38.4	49.8	+0.3
Means 1879-1888	36.9	39.7	41.1	45.9	52.3	58.3	62.0	61.2	56.7	48.3	43.6	39.2	48.8	-0.7
Means 1849-1888	38.7	39.9	41.5	47.3	52.7	59.3	62.7	61.9	57.2	50.1	42.9	39.8	49.5	..

Discussion has sometimes arisen as to the most desirable period to employ for the formation of temperature averages. It has been urged that periods of 50 years or more are too long, and that it is better to use periods of 10 or 20 years only. Periods of 10 years, however, would appear in this climate to be, from what has been remarked in the last paragraph, much too short. At the foot of the table of temperatures, monthly means have been added for each 10 years, and the differences of the means in the several months are as follows :—

January	3·4	May	2·8	September	0·8
February	2·1	June	1·5	October	8·0
March	1·8	July	1·8	November	1·1
April	2·4	August	1·2	December	2·6

The means, on the whole, evidently vary to the greatest extent in winter. Even employing means for 20 years, that for the first 20 years would differ from that for the last 20 years by nearly 2° in October, and by exactly 2° in December.

It has sometimes been imagined that the temperatures determined at Greenwich Observatory may be so influenced by the growth of London that they cannot be accepted as truly indicating the general variations of temperature. It does not appear, however, that this condition has been yet reached. In the paper on the variation of the temperature of the air in England, already referred to, I collected the results of the observations of temperature, contained in the *Quarterly Return* of the Registrar General, for the period 1849 to 1888, and gave means for groups of stations as arranged according to latitude; one set of means applying to stations situated between latitudes 51° and 52°, another to stations between 52° and 53°, and another to stations between 53° and 54°. It happens that the period covered by the numbers there given is precisely that of the present table, and Greenwich being situated as regards latitude in the middle of the 51°-52° zone, it is interesting to compare the changes indicated generally in that zone with the changes shown at Greenwich. Summer is taken to include the months from April to September, and winter those for the remaining portion of the year.

Period.	Winter.		Summer.		The Year.	
	Stations in zone 51°-52°.	Royal Observatory.	Stations in zone 51°-52°.	Royal Observatory.	Stations in zone 51°-52°.	Royal Observatory.
1849-1868	42·26	42·89	56·22	57·05	49·24	49·72
1869-1888	41·91	41·98	55·71	56·64	48·81	49·29
Difference	-0·85	-0·46	-0·51	-0·41	-0·43	-0·48

The decrease shown by these 20 years' means is somewhat greater in winter and less in summer at the Royal Observatory than generally in the zone 51°-52°. For the complete year the differences are identical. This is hardly surprising. The Royal Observatory is situated in the middle of Greenwich Park, within which buildings cannot be erected. The park abuts mainly on

the River Thames to the north, and is bounded on the south by the large open space of Blackheath. The Observatory thus occupies a very open position, and one not likely in the immediate future to be further encroached upon.

There is another matter on which I would add a few remarks. The corrections for diurnal range, given by Mr. Glaisher in his paper in the *Philosophical Transactions* before referred to, differ in some respects from those found from the Greenwich twenty years' reductions. In explanation of these differences various suggestions have been made; one that they may be due to the photographic thermometer, on which the 20 years' corrections depend, being sluggish, as compared with the thermometer of the revolving stand, on the eye observations of which the corrections determined by Mr. Glaisher depend; another suggestion is that the differences may be owing to the different manner of exposure. I do not think that the photographic thermometer can be said to be really sluggish.¹ Length of bulb does not imply sluggishness if the diameter be not excessive and other proportions appropriate. Very sensitive thermometers would be for such a purpose unsuitable. If the causes suggested have any real influence it is only in a minor degree. The true explanation of the differences between the two sets of corrections is due, in my opinion, mainly to the circumstance that Mr. Glaisher's corrections depend on five years' observations only, whilst the later corrections depend on the records of twenty years. It is not that the results essentially differ even as they stand, but rather that, comparing one month with another, there are irregularities which five years' observations (all that were at the time available) are not sufficient to eliminate. That this is so is easily seen. If the 24 hourly deviations in each of the 12 months be all summed together, without regard to sign, the sum for Mr. Glaisher's corrections is $960^{\circ}\cdot9$, and for the 20 years' corrections $968^{\circ}\cdot2$, indicating (dividing by $24 \times 12 = 288$) mean corrections of $8^{\circ}\cdot84$ in both cases. The point is that any systematic difference in the magnitude of the diurnal range would tell greatly in the sums of the hourly deviations just given. Or, dividing the year, we have for summer (April to September), sum of Mr. Glaisher's corrections $675^{\circ}\cdot0$, of the 20 years' corrections $670^{\circ}\cdot9$, indicating (dividing by 144) mean corrections of $4^{\circ}\cdot69$ and $4^{\circ}\cdot66$ respectively. For winter (including the remaining months), sum of Mr. Glaisher's corrections $285^{\circ}\cdot9$, of the 20 years' corrections $292^{\circ}\cdot3$, indicating mean corrections respectively of $1^{\circ}\cdot99$ and $2^{\circ}\cdot08$. On the whole there is thus agreement, the differences in individual months arising evidently from unavoidable irregularity in Mr. Glaisher's five years' series, affecting in greatest degree the months of April, June, and July.

I am aware that it has been pointed out that there are anomalies in Mr. Glaisher's corrections in some months of the year. The sum of the positive corrections in each month should balance the sum of the negative corrections, but in August, September, and October, the positive values are in excess. If,

¹ Some of the photographic records were exhibited showing the ready action of the photographic thermometer in cases of sudden depression of temperature during squalls, of which the anemometer record gave the period.

however, the 24 hourly values in each month correctly represent the amplitude of the observed temperature curve, the comparison with the newer 20 years' corrections will not be practically affected, and would not at all be affected if the positive and negative corrections in each month were equal in number, 12 of each.

It was mentioned in an earlier part of this paper that the corrections for reducing the mean of the readings of the maximum and minimum thermometers to the true mean, found by comparing, for the period 1849-1868, the maximum and minimum mean in each month, with the mean of 24 hourly values, had not been published. The corrections required by the maximum and minimum mean were found to be as follows :—

January	+ 0.1	May	— 0.7	September	— 1.1
February	— 0.4	June	— 0.7	October	— 0.6
March	— 0.7	July	— 0.9	November	— 0.1
April	— 0.8	August	— 1.2	December	+ 0.8

Unlike the corrections for diurnal range, these corrections sensibly differ in amount from those found by Mr. Glaisher, and given in his paper in the *Philosophical Transactions* for 1848, but a certain proportion of the difference is due to the circumstance that the readings of the maximum and minimum thermometers, on which Mr. Glaisher's corrections are founded, were taken at 10 a.m., thus causing the maximum and minimum means used by him (practically climatological day means) to be relatively higher than those referring to the civil day, to which the above corrections apply. (See *Quart. Jour. R. Met. Soc.* Vol. XVI. p. 218.)

I should like, in conclusion, to give some indication of the degree of accuracy attainable in the calculation of mean daily temperatures by the use of corrections applied to a few observations daily. The mean daily temperatures given, since the year 1878, in the report communicated weekly to the Registrar General, are found by combining the mean of the maximum and minimum readings, corrected by the numbers above given, with the mean of the ordinary eye observations (usually four) corrected for diurnal inequality, by corrections depending on the twenty years' reductions, varying both sets of corrections through each month as necessary. The temperatures have to be calculated for the Registrar General's weekly report in this way because, having to be got out so quickly, there is not sufficient time to tabulate the photographs. But a good approximation, indeed a very fair value of mean temperature, is thus found, as may be seen by comparing the daily values given in the Registrar General's weekly report in any year since 1878 with those afterwards determined from 24 hourly photographic values, and inserted in the Greenwich volume. Taking the year 1888, the last appearing in the table in this paper, and making comparison for the months of January, April, July, and October, we find that the mean daily temperature given in the Registrar General's report deviates from the photographic temperature, by more than 1°, only three times in January, twice in April, once in July,

and four times in October, the greatest deviation on any day in these months being respectively $1^{\circ}8$, $1^{\circ}4$, $1^{\circ}4$, and $2^{\circ}6$. The average deviation taken without regard to sign is respectively $0^{\circ}4$, $0^{\circ}5$, $0^{\circ}6$, and $0^{\circ}6$. The differences are evidently of accidental character, as is shown by the agreement of the monthly means. Thus the monthly means of the daily values in the Registrar General's report for January, April, July, and October 1888, are respectively $87^{\circ}8$, $48^{\circ}4$, $57^{\circ}9$, and $46^{\circ}0$, the monthly means of the values afterwards given in the Greenwich volume being respectively $87^{\circ}9$, $48^{\circ}5$, $58^{\circ}0$, and $46^{\circ}0$, which are practically the same. And in the whole eleven years, 1878 to 1888, there is no instance of a deviation greater than $0^{\circ}4$ between the corresponding monthly means. I think it will be seen from this comparison, that the values, given in advance in the Registrar General's report, are fairly representative and if required may be taken as representative of those, afterwards found from the photographs, which appear in the annual Greenwich volume. I do not pretend to say that the corrections for Greenwich would give equally satisfactory results for other places, but it is probable that they could be usefully employed for the comparison of results for different places at which the hours of observation were not the same.

On the Comparison of Thermometrical Observations made in a Stevenson Screen with Corresponding Observations made on the Revolving Stand at the Royal Observatory, Greenwich.

By WILLIAM ELLIS, F.R.A.S.

[Received May 11th. Read June 17th, 1891.]

THE use of the Stevenson screen for exposure of thermometers for determination of air temperature having become so general in England during late years, the Royal Meteorological Society, in the year 1888, appointed a Committee, of which I was myself a member, to consider the best pattern of screen for use by observers in connection with the Society. Their report, in which the adopted form of screen is described, will be found in the *Quarterly Journal*, Vol. X., page 92. Afterwards, in the year 1886, on my suggestion, a Stevenson screen of the pattern recommended was set up at the Royal Observatory, Greenwich, adjacent to the open revolving stand, commonly known as the "Glaisher Stand," for the purpose of comparing the indications of thermometers placed in the screen with those of the corresponding thermometers of the revolving stand. A description of the revolving stand will be found in the Introduction to the Greenwich annual volume. The screen

contains a maximum thermometer, a minimum thermometer, a dry bulb thermometer, and a wet bulb thermometer, and since the beginning of the year 1887 observations of these thermometers have been regularly made at the times at which the revolving stand thermometers were read, that is to say, the daily maximum and minimum have been observed, and readings of the dry bulb and wet bulb thermometers taken at 9 a.m., noon, 8 p.m., and 9 p.m., excepting that readings of the screen thermometers have not been taken on Sundays, but since the question is one of differences, this does not signify. The results at present available are those for the years 1887, 1888, and 1889; they are given in complete detail in the Greenwich annual volumes, but it seems desirable now to collect them in order to show what general conclusions may be drawn therefrom. The mean differences for the same month in different years are in such close agreement that it seems quite unnecessary to give in this paper the separate monthly differences, but only the mean values for each month as found from the observations made during the three years mentioned. These are contained in Table I. It should be explained, as respects the observations made at stated hours, that the order of observing the screen and revolving stand thermometers was reversed on alternate days, in order to avoid the introduction of any constant difference due to diurnal change.

Considering the numbers of Table I. it will be seen that the maximum readings in the Stevenson screen are lower than those of the revolving stand in all months of the year, not much lower in winter, but considerably lower during the summer months, also that the minimum readings in the screen are distinctly higher than those of the revolving stand throughout the year, the difference being somewhat greater during the summer and autumn than at other times. The mean of the maximum and minimum readings in the screen differs little in the winter months from that of the revolving stand mean, but is lower in other months of the year, the difference being greatest in the summer months, depending on the greater difference of the maximum readings at that period of the year.

The readings of the dry bulb thermometers of the Stevenson screen and revolving stand, as taken at definite hours, are in much closer agreement than are those of the self-registering thermometers; the screen readings being at noon and at 8 p.m., even in summer, only a few tenths of a degree below those of the revolving stand. This is in striking contrast with the larger differences existing in summer, between the readings of the maximum thermometers of the screen and revolving stand. In the latter part of the year the screen readings at 8 p.m. are higher than those of the revolving stand, the values for the separate months in each of the three years being in close agreement in this respect. At 9 a.m. the differences are in most months small; at 9 p.m. the screen readings are higher throughout the year.

The differences between the readings of the Stevenson screen and revolving stand wet bulb thermometers, at the stated hours of observation, are in close accord with the differences between the corresponding dry bulb readings, being usually of the same sign and somewhat less in amount; indicating that,

TABLE I.

Month.	Excess of Stevenson Screen Readings over Readings on the Revolving Stand, from observations made during the years 1887, 1888 and 1889.										
	Self-Registering Thermometers.			Dry Bulb Thermometer.				Wet Bulb Thermometer.			
	Maximum.	Minimum.	Mean of Max. and Min.	9 a.m.	Noon.	3 p.m.	9 p.m.	9 a.m.	Noon.	3 p.m.	9 p.m.
January ..	-0°30	+0°27	-0°02	+0°03	-0°10	-0°03	+0°13	-0°03	-0°03	+0°03	+0°10
February ..	-0°43	+0°30	-0°06	-0°03	-0°17	-0°07	+0°10	0°00	-0°07	+0°03	+0°13
March	-0°87	+0°37	-0°25	-0°10	-0°23	-0°17	+0°10	-0°17	-0°20	-0°10	+0°07
April	-1°63	+0°37	-0°63	-0°23	-0°30	-0°20	+0°20	-0°10	-0°13	-0°07	+0°27
May	-1°77	+0°37	-0°70	-0°20	-0°47	-0°37	+0°27	-0°13	-0°27	-0°13	+0°23
June	-2°03	+0°43	-0°80	-0°23	-0°50	-0°37	+0°17	-0°13	-0°30	-0°17	+0°07
July	-2°23	+0°47	-0°88	-0°27	-0°40	-0°40	+0°17	-0°20	-0°17	-0°13	+0°10
August	-1°97	+0°53	-0°72	-0°07	-0°27	-0°10	+0°23	-0°13	-0°20	-0°13	+0°17
September ..	-1°17	+0°57	-0°30	0°00	+0°10	+0°03	+0°20	-0°07	+0°03	+0°03	+0°13
October	-0°87	+0°57	-0°15	-0°03	+0°10	+0°10	+0°23	0°00	0°00	+0°07	+0°20
November ..	-0°47	+0°37	-0°05	0°00	0°00	+0°13	+0°13	0°00	-0°07	+0°10	+0°13
December ..	-0°13	+0°27	+0°07	0°00	-0°07	+0°17	+0°17	-0°03	-0°07	+0°13	+0°13
Summer Mean, April to September }	-1°80	+0°46	-0°67	-0°17	-0°31	-0°24	+0°21	-0°13	-0°17	-0°10	+0°16
Winter Mean, October to March }	-0°51	+0°36	-0°08	-0°02	-0°08	+0°02	+0°14	-0°04	-0°07	+0°04	+0°13
Yearly Mean	-1°16	+0°41	-0°37	-0°09	-0°19	-0°11	+0°18	-0°08	-0°12	-0°03	+0°14

on the whole, the revolving stand dry and wet bulb readings and the screen dry and wet bulb readings would independently give much the same values of dew point and of humidity.

If for the dry bulb and wet bulb thermometers we take the mean of the differences of the screen and revolving stand temperatures at 9 a.m., noon, and 3 p.m. to represent the day condition, and the 9 p.m. difference to indicate the night condition, we obtain the numbers given in Table II.

Briefly, then, we have these results. The maximum temperature in the screen is lower than that of the revolving stand, in summer much lower, and the minimum temperature is higher; whilst the readings of the screen and revolving stand dry bulbs, and of the screen and revolving stand wet bulbs, as taken at stated hours, show differences of a very much less marked character; so much so, that any ordinary combination of observations of the screen dry bulb would give a mean temperature practically similar to a like combination of observations of the revolving stand dry bulb.

It has been affirmed that the readings on the revolving stand by day in summer are unduly influenced by radiation from the ground and from the

TABLE II.

Month.	Excess of Stevenson Screen Readings over Readings on the Revolving Stand, from observations made during the years 1887, 1888 and 1889.					
	Dry Bulb Thermometer.			Wet Bulb Thermometer.		
	By Day.	By Night.	Mean.	By Day.	By Night.	Mean.
January	—0°03	+0°13	+0°05	—0°01	+0°10	+0°05
February	—0°09	+0°10	0°00	—0°01	+0°13	+0°06
March	—0°17	+0°10	—0°03	—0°16	+0°07	—0°04
April	—0°24	+0°20	—0°02	—0°10	+0°27	+0°08
May	—0°35	+0°27	—0°04	—0°18	+0°23	+0°03
June	—0°37	+0°17	—0°10	—0°20	+0°07	—0°06
July	—0°36	+0°17	—0°09	—0°17	+0°10	—0°03
August	—0°15	+0°23	+0°04	—0°15	+0°17	+0°01
September....	+0°04	+0°20	0°12	0°00	+0°13	+0°06
October	+0°06	+0°23	0°14	+0°02	+0°20	+0°11
November	+0°04	+0°13	0°09	+0°01	+0°13	+0°07
December	+0°03	+0°17	0°10	+0°01	+0°13	+0°07
Summer Mean, April to Sept. }	—0°24	+0°21	—0°02	—0°13	+0°16	+0°01
Winter Mean, Oct. to March }	—0°03	+0°14	+0°06	—0°02	+0°13	+0°05
Yearly Mean	—0°13	+0°18	+0°02	—0°08	+0°14	+0°03

white buildings in the meteorological court, and the comparison of the revolving stand maxima with the Stevenson screen maxima seems to give support to such idea. But if this be the explanation of the higher revolving stand maxima, the dry bulb readings of the revolving stand and screen at noon and at 8 p.m. should show similar differences, instead of differences which are in every way so very much smaller, and which, indeed, in some months are persistently reversed in direction, the screen readings being the higher. There is nothing in the positions which the various thermometers occupy on the revolving stand which should cause anomalies. The stand is 4 ft. 6 ins. wide, the bulbs of the different thermometers are all placed towards the centre of the stand, which is kept with its inclined side always towards the sun, whether the sky be clear or cloudy, being turned through a certain angle at stated times every day.

We have now, however, some direct evidence bearing upon the question of radiation. As regards radiation from the ground, it may be mentioned that it was because of a suggestion that ground radiation might affect the readings of the thermometers on the revolving stand that in the year 1878 a horizontal circular board, 8 ft. in diameter, was fixed on the post carrying the thermometer frame, in a position below the frame, at a height of 2 ft. 6 ins. above the ground, with the object of affording protection to the thermometers in this respect. In the summer of the year 1886, some experiments were made to ascertain whether the removal of the board produced any difference

of reading. On four days of high temperature and bright sunshine, observations were made of the dry bulb and wet bulb thermometers, at short intervals, with the circular board alternately removed and attached, the details of which observations are given at the end of the Introduction to the *Greenwich Magnetical and Meteorological Observations* for the year 1887. All the observations made are published, and the following are the results :—

1886.		Duration of Experiment.	Number of Comparisons.	Mean reading of dry bulb thermometer on revolving stand with circular board		Excess with circular board removed.
				removed.	attached.	
		h. m.		°	°	°
August	21	2.40	5	71.5	71.9	—0.4
„	28	3.30	10	71.0	70.9	+0.1
„	30	5.30	16	88.5	88.9	—0.4
„	31	3.50	11	85.7	85.6	+0.1
Means				77.92	78.07	—0.15

The concluded mean reading of the dry bulb thermometer with the circular board removed is thus slightly less than with the board attached. In the case of the wet bulb thermometer, the corresponding differences were :—0°.2, +0°.1, 0°.0, and +0°.1, the mean difference being 0°.00. This indicates that the removal of the circular board produces no real difference in the readings.

As respects radiation from the surrounding white buildings, the erection of the Stevenson screen afforded an excellent opportunity of testing this particular question. The screen is placed a little to the east of the revolving stand, both occupying positions distant somewhat more than 80 ft. south of the Magnet House, which building the Stevenson screen faces ; so that, on opening the front vertical door, the screen thermometers become exposed to the direct influence of any radiation from the building equally with the thermometers on the revolving stand ; an influence which, on closing the screen door, becomes, for the screen thermometers, completely shut off. On four days of high temperature and bright sunshine in the summer of the year 1887 observations were made of the dry bulb and wet bulb thermometers, at short intervals, with the door of the screen alternately open and shut. All details are given in the Greenwich volume for 1887, and all the observations made are published.

1887.		Duration of Experiment.	Number of Comparisons.	Mean reading of the dry bulb thermometer of the Stevenson Screen with the door of the screen		Excess with door open
				open.	shut.	
		h. m.		°	°	°
July	4	3.15	6	87.1	87.5	—0.4
August	3	1.10	2	69.7	69.5	+0.2
„	4	1.40	3	70.9	71.3	—0.4
„	6	3.40	7	88.1	82.9	+0.2
Means				77.70	77.80	—0.10

The concluded mean is thus, in an insignificant degree, lower with the door open than with the door shut. In the case of the wet bulb thermometer the corresponding differences were $-0^{\circ}\cdot 2$, $0^{\circ}\cdot 0$, $0^{\circ}\cdot 0$, and $-0^{\circ}\cdot 8$, the mean difference being $-0^{\circ}\cdot 12$. Corresponding readings of the dry bulb thermometer of the revolving stand were also taken, the mean being $78^{\circ}\cdot 75$, or $1^{\circ}\cdot 05$ higher than that of the screen dry bulb $77^{\circ}\cdot 70$, no very remarkable difference at a temperature so extreme.

Further, when the new thermograph was set up on the ground south of the meteorological court, known as the south ground, the thermometer bulbs were carefully protected from all possible radiation effects by two boards on the north side and two on the south side, an east-end board, a west-end board, and one horizontal board below, but with free circulation of air between all the boards. On five days of high temperature and bright sunshine during the summer of the year 1886 the north and south boards were alternately removed and attached at short intervals, and the photographic record of the dry bulb thermometer independently tabulated by two different observers, whose tabulations were practically identical. All details are to be found in the Greenwich volume for 1887, and, as before, no results have been omitted.

1886.		Duration of Experiment.	Number of Comparisons.	Mean reading of the dry bulb thermometer of the new thermo- graph for inter- vals during which the north and south boards were		Excess with boards removed.
		h.m.		attached.	removed.	
July	5	2.20	8	78 ^o ·7	78 ^o ·8	+0 ^o ·1
"	7	2.20	8	81·9	81·7	—0·2
"	20	4.20	6	70·7	70·7	0·0
"	21	5. 0	7	80·9	81·1	+0·2
Sept.	1	5.15	10	80·5	80·6	+0·1
Means				78 ^o ·54	78 ^o ·58	+0 ^o ·04

With the boards removed, the thermometer was open to any radiation from the surrounding wooden buildings and fences. Practically the removal of the boards produced no effect, and, indeed, before the commencement of regular work with the new thermograph on January 1st, 1887, one north board and both south boards were permanently removed.

The experiments made with the circular board of the revolving stand show that its removal produced no real difference in the thermometer readings. The experiments made with the Stevenson screen show that the screen readings are practically similar both with the door of the screen open and shut, and in the experiments with the thermograph the removal of the protecting boards produced no real change of reading. Further, these experiments receive corroboration from the near agreement of the revolving stand readings with the screen readings at the stated hours of observation. In such widely

different conditions of exposure, indeed, the differences really observed (see second and third divisions of Table I.) are such as may reasonably be supposed to be in part due to contraction of the range in the screen, acting to depress the screen readings by day and raise them by night, and so far the revolving stand thermometers do not appear to be influenced by radiation in the way that has been alleged. It would seem that, for the circumstance that the maximum readings on the revolving stand are so much higher in summer than those of the screen, as compared with the lesser differences between the readings taken at stated hours, some other explanation must now be sought. It is to be remembered that on a fine day in summer the temperature is frequently subject to fluctuations of brief duration. The maximum is, of course, the highest point touched, no matter for how short a time such temperature is maintained, and the screen maximum thermometer may be less sensitive to such changes than is the more completely exposed revolving stand maximum. The readings taken at stated times, on the other hand, are as likely to fall at the base as at the crest of such fluctuations. But even in the absence of any sufficient explanation of this apparent discordance, the observed facts, considered as a whole, do not appear to at all warrant the conclusion that, because the revolving stand maxima are higher than the screen maxima, they are on that account necessarily wrong.

It has been suggested that, after having carried on for a few years comparisons of the revolving stand and Stevenson screen thermometers, the use of the revolving stand should be discontinued. That would rather be to replace an imperfect stand by an imperfect screen. Each may have its faults. But it seems every way better to let stand and screen be both at present maintained, especially when there is a willingness to carry on duplicate observations, rather than to contemplate the immediate interruption of a long series of observations made in one definite way, and commenced long before the Stevenson screen was thought of.

The mean daily and monthly values of air temperature, as given in the annual volume have, since the year 1877, been formed from hourly measures of the photographs reduced to the dry bulb of the revolving stand. Table II. of this paper shows that values so obtained are practically such as would be found were the photographic values reduced to the screen dry bulb, instead of to the revolving stand dry bulb, that is to say, the concluded temperatures would differ only in an insignificant degree. Such being the case, it is a further argument for retaining at present the existing system, rather than replace the revolving stand by another form, which would introduce into mean values a small but doubtful correction, as regards absolute truth, but yet one that, in making any fundamental change, should properly be taken account of, although otherwise scarcely worth consideration.

Finally, it should be mentioned that all thermometers are carefully compared every year with the standard thermometer No. 515, a thermometer kindly supplied in the year 1875 to the Royal Observatory by the Kew Committee of the Royal Society, and that all corrections for index error are rigorously applied.

ADDENDUM.

It has occurred to me that it might be interesting to add to the preceding paper a comparison of the observations of the thermometers placed on the roof of the Magnet House with the corresponding observations of the thermometers of the revolving stand. The roof thermometers are mounted in a louvre boarded shed or screen, so constructed as to give free circulation of air, with protection from radiation. It is open towards the north. The thermometers are a maximum thermometer, a minimum thermometer, and a dry bulb thermometer, but no wet bulb. The bulbs of the thermometers are 4 ft. above the platform and 20 ft. above the ground. As with the Stevenson screen thermometers, readings have not been taken on Sundays. The observations were commenced at the beginning of the year 1886, and the results for four years are now available.

Month.	Excess of Roof Thermometer Readings over Readings on the Revolving Stand from observations made during the years 1886, 1887, 1888, and 1889.						
	Self-Registering Thermometers.			Dry Bulb Thermometer.			
	Maximum.	Minimum.	Mean of Max. and Min.	9 a.m.	Noon.	3 p.m.	9 p.m.
January	+0°30	+0°15	+0°23	+0°37	+0°22	+0°35	+0°40
February	-0°23	-0°10	-0°07	+0°23	-0°12	+0°12	+0°30
March	-0°50	-0°13	-0°18	+0°10	-0°30	+0°02	+0°33
April	-1°25	-0°20	-0°53	-0°23	-0°52	-0°35	+0°22
May	-1°27	-0°25	-0°51	-0°20	-0°70	-0°38	+0°33
June	-1°63	-0°28	-0°67	-0°35	-0°95	-0°50	+0°12
July	-1°77	-0°32	-0°73	-0°45	-0°78	-0°37	+0°20
August	-0°53	-0°28	-0°62	-0°17	-0°42	-0°15	+0°43
September	-0°90	-0°32	-0°29	-0°15	-0°20	+0°02	+0°45
October	-0°47	-0°33	-0°07	+0°05	-0°15	+0°23	+0°42
November	-0°10	-0°35	+0°12	+0°40	+0°12	+0°30	+0°35
December	+0°33	+0°30	+0°31	+0°40	+0°30	+0°45	+0°48
Summer Mean—April to Sept...	-1°39	+0°27	-0°56	-0°26	-0°59	-0°29	+0°29
Winter Mean—October to March	-0°11	+0°23	+0°06	+0°26	+0°01	+0°25	+0°38
Yearly Mean	-0°75	+0°25	-0°25	0°00	-0°29	-0°02	+0°34

DISCUSSION.

Mr. MAWLEY said that he had made a comparison of the various Greenwich mean temperatures as obtained by Mr. Glaisher, Mr. Eaton, and Mr. Ellis, in the cases of years where the records employed overlapped, and could find very little agreement between them. He then quoted some figures showing the divergencies of the various means. He thought it would have been better to have kept from the first to the simple means as deduced from the daily maximum and minimum readings. Regarding the comparison between the tempera-

tures registered on the revolving stand and in the Stevenson screen, Mr. Ellis's figures showed greater differences between the two forms of exposure than he (Mr. Mawley) had obtained from six years' observations made with similar screens at Addiscombe. His experience in observing with different screens had taught him that a great deal depended upon whether there was a good lawn under the thermometer screen. He could not understand why during the summer months the mean differences between the temperatures on the two screens at Greenwich should come out about four times as great in the case of the maxima as in that of the 8 p.m. readings.

Mr. SYMONS agreed with Mr. Ellis that it would be a great pity to give up the observations made on the revolving stand in favour of those made in the Stevenson screen, and he sincerely hoped that the old form of stand would continue in use, as it had now done service at Greenwich for so many years; and he hoped that the authorities would be able to arrange that in future the readings of the thermometers in the Stevenson screen should be taken on Sundays, so that there would be available (1) a record strictly comparable with that of past years, and (2) a record strictly comparable with those from the inspected stations of the Royal Meteorological Society. He considered that meteorology at the Royal Observatory was badly treated by the authorities, and he thought it would be an advantage if a large part of the spectroscopic and astronomical work were carried on at a more suitable locality in the country, so that better provision could be made for the meteorological department.

Mr. C. HARDING said that the means given by Mr. Ellis were exceedingly valuable, and it was a great gain that correction had been made for the gaps which from various causes occurred in the series of observations. He had always looked upon the Greenwich volume containing the reduced temperature observations for the 20 years 1849-68 as a splendid piece of work, and a work of high scientific value which supplied a great need for the ordinary inquirer. He had shared the opinion expressed by the Astronomer Royal in the text which accompanies the Tables "that the whole work may be considered as a model of accuracy on a very large scale." He was greatly surprised to notice the large differences which were shown between the values in the Greenwich volume and Mr. Ellis's figures, differences which from their magnitude greatly lessen the usefulness of the Greenwich reductions. He had tabulated and taken the averages of the daily maximum and minimum readings at Greenwich since 1840, and on comparing the means thus obtained with Mr. Ellis's figures, he found a very good agreement. He quoted certain differences which occur between the values in the Greenwich volume for 20 years, and those given now by Mr. Ellis. In the volume for 20 years the January and February means for 1849 are respectively $42^{\circ}7$ and $42^{\circ}3$, whereas, according to Mr. Ellis, they should be $40^{\circ}8$ and $48^{\circ}1$, so that instead of February being colder than January by $0^{\circ}4$ it is really warmer by $2^{\circ}8$. According to the Greenwich volume December 1860 is $8^{\circ}5$ warmer than December 1859, but Mr. Ellis's values show it to be $0^{\circ}3$ colder, and this sort of difference occurs very frequently where opportunity is afforded for comparison. It is these differences which, being known to exist, will greatly lessen the value of the Greenwich volume. No attempt having been made to correct for the absence of observations throughout the series of the Greenwich observations also vitiates very greatly other parts of the work—for example, in May 1863 the mean air temperature and the mean temperature of evaporation at 8 a.m. are both $44^{\circ}6$, but it is seen that the dry bulb is obtained from 25 days' observations, and the wet bulb from 20 days' only, so that practically no comparison is possible. In 1862 the July air temperature mean is obtained from 27 days, and the evaporation from 17 days. He regretted this want of judgment in the discussion, as he attached the very highest possible importance to the series of observations made at Greenwich, which in many ways stood unique in its position with regard to meteorology.

Mr. ROSTRON said that he agreed with Mr. Ellis that it was an utter fallacy to take averages of short series of years. Ten years was certainly much too short a period, and he did not consider 50 years was by any means too long. In fact, he was of opinion that for the purpose of meteorological averages the longer the series of years the better was the average obtained. He illustrated the truth of his remark concerning averages deduced from short series of years by instancing the air temperature at Greenwich in the month of October, which, during the 12

years 1855-1866 both inclusive, was continually in excess, but had now for several years past been in defect of the mean. The month of February, during the last 80 years, exhibits similar "eccentricities."

Mr. TRIPP thought that if it were possible to discover cycles of years from such a series of observations as those placed before them by Mr. Ellis, the true mean should contain a due proportion of the high and low readings in each cycle.

Mr. ELLIS said that in the table of mean temperature now presented the results depend on 24 hourly values on each day, adopting, as required, values from the eye observations for days on which the photographs were imperfect or wanting, so that the whole period is completely represented. Results depending in this way fundamentally on hourly temperatures necessarily supersede for the period in question all other values, and he hoped to see also published, in due course, the corresponding daily values from which the present monthly results are formed. For those who prefer the simple mean of the maximum and minimum temperatures, the Greenwich volumes have already continuously supplied the necessary information. He considered it to be quite possible that at different places the differences between the readings on an open stand and in a closed screen might not be similar, and yet be equally true for each particular case. It seemed to him that meteorologists too often expected an accuracy and an agreement of results not at present attainable. In regard to the 20 years' reductions, their value consists in the full and complete information afforded on the diurnal inequalities of meteorological elements in relation to which the omission of a few days in some months, owing to imperfect photographs, becomes of little practical importance. Photographic processes, a quarter of a century ago, had not the certainty of those of modern times. He did not understand the surprise expressed at the monthly means of air temperature therein contained varying from the means of the table now presented, since a little examination of the book would show that the monthly means collected in Table 52 are those appearing in Tables 88 to 49, against the columns containing which means is to be found another column giving the number of days in each month on which the several means depend. He thought that the collected monthly means of Table 52 should have been corrected for omitted days, but the work was not done under his direction, although he had to see it through the press. In two tables which, however, he was able to add to the 20 years' reductions, Tables 21 and 77, giving mean daily values of atmospheric pressure and of air temperature (a 20 years' average), he did take account of days on which photographs were wanting, as is noted in the introduction to the work. What has been said on the non-correspondence of days employed in the tables of air and evaporation temperatures, Tables 88 to 67, is likely to produce an erroneous impression as to the extent of such non-correspondence. In 20 years there are 240 months, and only in 8 months does non-correspondence exist, and in these the difference exceeds two days in a month on four occasions only, June 1858, May 1863, July 1861 and 1862. For the remaining 232 months the hourly values of the two elements are strictly comparative. All this is easily seen, as the tables themselves give complete information on these points. He did not say that it would not have been better to have avoided more completely such non-correspondence; he would have preferred to have done so; at the same time it should be understood that this affected the work only in a slight degree, and could not reasonably be said to detract from the real value of the results.

PHONOMETER.

By W. F. STANLEY, F.R.Met.Soc., F.G.S.

[Received May 22nd.—Read June 17th, 1891.]

THIS instrument, which is really a new form of chronograph, has been designed for the purpose of ascertaining the distance of a gun by observations of the flash and the report of its discharge, by noting the difference of time that light and sound take in reaching the observer. It is introduced to this Society for the object that it provides a means of measuring the distance of an electric discharge, by the difference of time between which lightning is observed in the flash and the following report of the thunder is heard, providing by this means an item of meteorological measurement not heretofore recorded.

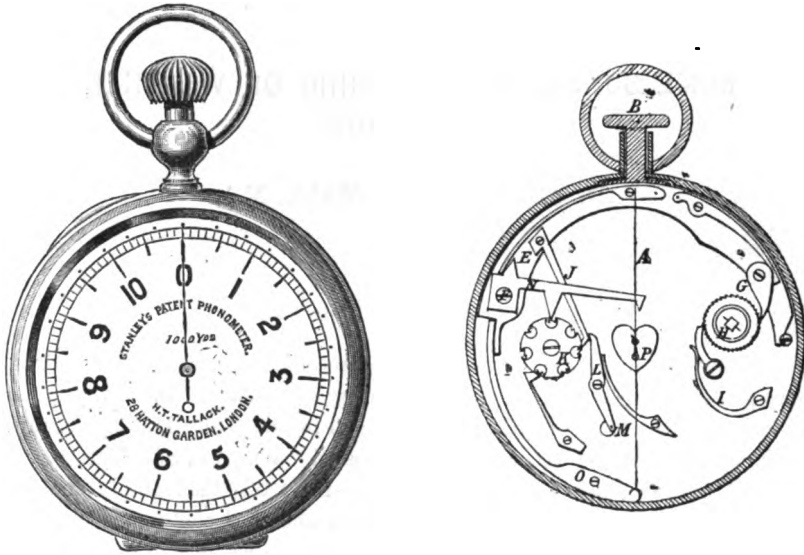
The manipulation of the phonometer is simpler than that of any form of chronograph, in that for complete indication of an observation, there is only one button to be pressed. This button acts by simple pressure in setting its time-going apparatus free, and stops instantly by the release of the pressure, leaving the indication, according to the divisions of the dial, either to the exact time between the pressure and the release, or the distance (calculated from the mean velocity of sound in air) in yards. This indication is without any calculation of difference of time as with the chronograph, as the time-going apparatus starts uniformly from zero at the instant of pressure, and entirely stops upon release of the pressure. The index-hand is afterwards returned to zero by a second pressure upon the same button employed in the observation, where it remains ready at any time for future use.

The construction of the Phonometer varies from a chronograph only in that it possesses additional parts. The chronograph, which is a constantly-going watch, requires most delicate manufacture to enable it to keep in order under constant wear. This instrument is going only at the time it is in use, by which there is no appreciable wear upon its most delicate parts, that may therefore be made to the highest degree of sensitiveness without danger of such parts becoming dull. This instrument is so constructed that the pressure given in returning the index-hand to zero shall also wind the spring more than sufficiently for another observation, means being at the same time provided that the spring cannot be overwound. There is, therefore, no key or winder required, and no risk that it shall not be ready at any moment for taking an observation. The index-hand makes the entire circuit of the dial in 30 seconds, but so long as the button is held down it goes on continuously, by which means as many half-minutes as desired may be taken. The half-minute revolution enables the dial to be made with very open space readings.

The details of the instrument, beyond the escape system of a perfectly sensitive chronograph for the going part, are shown in the diagram plan of the

instrument, which is represented with the outer case and dial removed, thereby showing the mechanism, which is worked by the pressure of the push *B*.

A is the index hand; *E* is a piece of steel, working on screw *F* when pushed down by the push *B*. *G* is a small pawl attached to steel piece *E*, which turns the ratchet wheel *H* connected to the mainspring arbor whenever *E* is pushed down by pushing *B*, the ratchet wheel *H* being held in position by pawl and spring *I*.



Connected also to the steel piece *E* is another pawl, *J*, which engages in lower part of the castle-wheel *K*, and partly revolves it when *E* is pressed down. This pawl *J* is extended to come in contact with the lever *L* when pressed down, and turns it slightly on its centre, which movement shifts the lower end carrying a pin *M* projecting inwards, and against the rim of the escapement wheel, away from the escapement wheel, thus setting the escapement free to work; at the same time the castle wheel *K* is partly revolved, which raises the lever *N* free from the heart-shaped frictional return piece for the index-hand. It will thus be seen that the act of pressing the push *B* partially winds the main spring, sets the escapement free, and raises the lever *N* from holding the index-hand at zero; and the act of releasing the pressure causes the steel piece *E* to return to its normal position by the spring *O*, thus removing the extension of pawl *J* from the lever *L*, which again stops the escapement wheel, leaving the index-hand at whatever distance it has travelled during the time the push was held down.

By pressing the push again the castle wheel *K* is arranged to drop the lever *N* upon the heart *P*, which returns the hand to zero, and the instrument is then ready to record again.

Beneath the plate carrying the above described mechanism the ordinary train of wheels of a chronograph are arranged.

DISCUSSION.

Mr. INWARDS said that this instrument was extremely ingenious, but he should like to know how the escapement was arrested and released so quickly.

Mr. STANLEY, in reply, said that in this instrument, as in all chronographs, the escapement was constructed on what was known as the cylinder principle. When the button at the top was pressed, a slightly-inclined cam started the escapement, and so set the instrument in motion. Its action being almost instantaneous, the impact probably did not occupy the twentieth part of a second.

SOME SUGGESTIONS BEARING ON WEATHER PREDICTION.

By ALEX. B. MacDOWALL, M.A.

[Received April 11th.—Read June 17th, 1891.]

The following suggestions, arising out of a recent study of certain records, may perhaps be not unworthy of the Society's consideration. They relate to three things: I. The distribution of rainfall in the year; II. Days of rain in June to September; III. What may be called "Waves of Sunshine."

I. *The distribution of rainfall in the year.*—If we take the monthly amounts of our rainfall in a series of years, and make a smoothed continuous curve of them, smoothed by means of three month averages, we find in most years a pretty obvious maximum for the year; usually the crest of a wave, which slopes more or less regularly for several months on either side.

Consider these maxima in the yearly curves, and the intervals between them. Taking the Chiswick record from 1840 to 1859, and the Greenwich record from 1860 to 1890, it appears that while the maxima occur most often, as might be expected, in the autumn months (October having most), they may be found, apparently, in any month of the year (unless March be excepted, which, in this series of 51 years, never shows a maximum).

The three months represented in each of these highest points have (in general) the highest three consecutive months' rainfall of the year. (Where the highest point occurs in January or December, a month of the adjoining year, before or after, is included in the consideration). What proportion (it may be asked) have these three months of the total rainfall of the year? From an examination of the latter half of the period, they seem to have, on an average, about $\frac{1}{3}$ ths of the total; that is, nearly one-half. But in some cases the amount is over one-half, and in others it goes down under one-third.

The interval from one yearly maximum to the maximum of the next year is seldom exactly a year; and seldom the same length in one case as it was in the case just before. As a rule, it alternately lengthens and shortens; if in

one year longer *e.g.* than in the year before, next year it is shorter than this longer one, and so on. This will appear from the following table, which gives for each year the number of the maximum month, and the length of the interval it terminates :—

Year.	No. of max. months.	Interval in months.	Year.	No. of max. months.	Interval in months.
1840	10	...	1866	2	5 <i>e</i>
1841	10	12	1867	8	18
1842	10	12	1868	12	16
1848	6	8	1869	1	1 <i>e</i>
1844	10	16	1870	11	22
1845	12	14	1871	8	9
1846	9	9 <i>e</i>	1872	11	15
1847	11	14	1878	1	2
1848	7	8	1874	10	21
1849	8	18	1875	8	10
1850	12	16 <i>e</i>	1876	12	16
1851	2	2	1877	1	1
1852	10	20	1878	5	16
1858	7	9	1879	7	14
1854	6	11	1880	10	15
1855	6	12 <i>e</i>	1881	9	11
1856	9	15 <i>e</i>	1882	10	18
1857	9	12	1883	10	12
1858	6	9 <i>e</i>	1884	12	14
1859	9	15	1885	10	10
1860	6	9	1886	11	18
1861	12	18	1887	10	11
1862	4	4	1888	7	9 <i>e</i>
1868	9	17	1889	6	11
1864	10	18	1890	7	18 <i>e</i>
1865	9	11 <i>e</i>			

This table further shows that the rule, as just indicated, is not universal. Excluding two cases at the outset, where the interval is exactly a year, we find ten exceptions (or exceptional years, marked *e* in table). These anomalies are of the following nature: (1) Lengthening of the interval twice in succession after a normal lengthening (2 years); (2) Shortening twice in succession after a normal shortening (2 years); (3) Lengthening once after a normal lengthening (2 years); (4) Shortening once after a normal shortening (4 years). The curve of those variations is normally, then, a zig-zag one, with a relative maximum every second year; and likewise a relative minimum.

The intervals between the maxima in our principal curve vary in length from one to 22 months. The exceptions seem to have occurred chiefly in periods of rainfall that were generally under average; and in some of the exceptional years the maximum is not very pronounced.

We have here, then, it is suggested, a means of estimating beforehand, with considerable reason, whereabouts in a commencing year (*i.e.* before or after such and such a month) the maximum (as above explained) will probably fall; that is, we have indications where we should look for the three consecutive months giving the greatest (three consecutive months) rainfall. If the maximum of last year was further apart from the one just before, than that from the one before it, we should expect the current interval to be shorter than the last; in the opposite case, longer.

It may be mentioned that the rainfall data for Paris give very similar results.

II. *Days of rain in June to September.*—The well-known saying about St. Swithin's Day is of course often falsified by observed facts. But the widespread idea, evidently related to it, that wet or dry weather, coming about the time of the summer solstice, has a tendency to persist, appears to find some vindication in experience.

I propose to offer here some evidence for the proposition that "the total number of days of rain ($\cdot 01$ in. and over) in July to September varies, on the whole, with the number of days of rain in June."

The data are presented in the following table; the stations selected being Barnstaple, Borrowdale (Seathwaite), Aberdeen, Chiswick, and London. The figures for the first three are obtained from Mr. Symons's *Meteorological Magazine*.

BARNSTAPLE (1866-88).

Days rain June.	No. of cases.	Average Days rain July-Sept.	Extremes July-Sept.
0 to 8	7	89.7	29—55
Over 8 to 12	6	46.2	36—59
Over 12 to 16	5	49.6	42—61
Over 16	4	55.0	58—63

BORROWDALE (Seathwaite) (1866-88).

0 to 11	8	52.2	89—61
Over 11 to 15	5	59.6	48—67
Over 15	8	61.8	46—75

ABERDEEN (1866-88).

0 to 11	7	48.7	35—59
Over 11 to 16	8	50.7	34—64
Over 16	7	57.4	44—70

CHISWICK (1826-69).

0 to 8	11	34.1	22—44
Over 8 to 12	11	39.2	32—52
Over 12 to 16	12	40.8	28—60
Over 16	10	44.6	36—58

GREENWICH (1870-89).

0 to 7	6	35.6	28—41
Over 7 to 12	6	37.6	33—43
Over 12	8	43.4	37—53

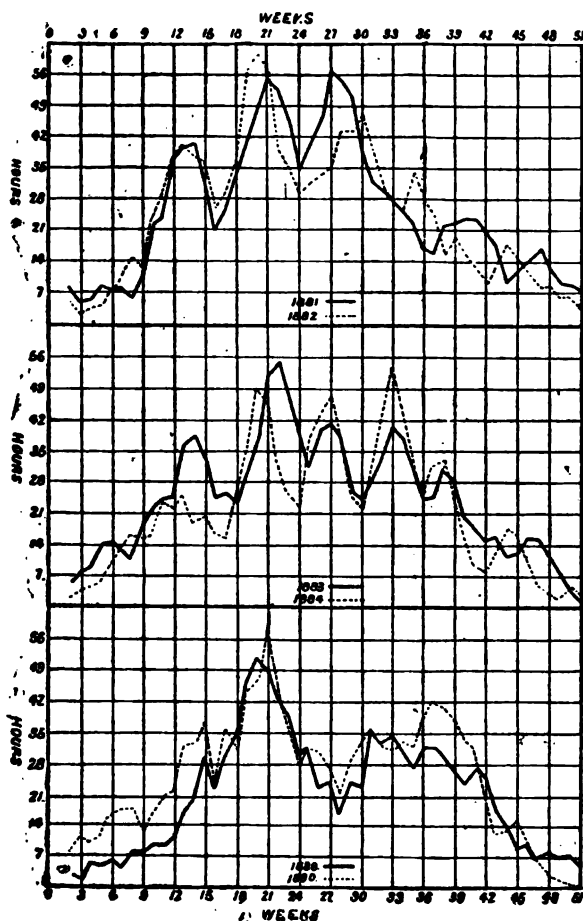
The plan adopted is first to classify the years (in the periods indicated for each station) according to the number of days of rain in June (0 to 8, over 8 to 12, and so on); then, putting down for each year in a given group the total number of days of rain in July to September, to take the average of those totals for the group. We thus get an ascending series of averages for each station, with an ascending series of days of rain in June. Thus, in the case of Barnstaple (perhaps the best example), we have, with 0 to 8 days' rain in June, 89.7 days' rain in July to September, on an average of seven years; and the average rises in the next two groups, till, with over 16 days' rain in June, we have 55 days' rain, on an average, in July to September; showing an extreme difference of 15.8 days. The extremes of variation of the number of days of rain in July to September are also indicated for each group; and it will be seen that while the maxima and minima both form in general ascending series, this rule is occasionally broken, and the range is in any case wide; which, no doubt, detracts from the practical value of the facts. Yet some useful indications, it seems to me, might be derived from this view of the case, especially where June is found to be considerably above or below its average of days of rain. Thus, recurring to Barnstaple, consider what we have to guide us in forecasting the number of wet days from July to September. Apart from a consideration of June, we have the general average number of days' rain in those three months (say 46), representing, let us suppose, the maximum of probability; with a possible range (according to those 22 years) from 29 to 68 (or 84). Considering June, on the other hand, we have, with a dry June, an average of about 40 days' rain in the next three months, with a wet June, an average of 55. And the probability may be supposed to diminish from those averages to the extremes of 29 and 55 in the one case, and 58 and 68 in the other. The series of years is here too short; and I make use of it merely to show how the principle may be applied, and how some little advantage, in greater definiteness of forecast, may possibly attach to its application.

III. *Waves of Sunshine*.—I would invite attention to the smoothed curves of bright sunshine obtained from the weekly Greenwich values (smoothed by means of three weeks averages). The accompanying diagram contains six of these as specimens (viz. for the years 1881, 1882, 1888, 1884, 1888, and 1890).

One feature apparent in many of these curves is the succession of distinct, more or less regular waves, varying in number up to six or seven at most in the year. Then the same type of curve tends to recur, apparently, the maxima of both, perhaps, even falling about the same time; and likewise the minima. Thus one sees at once the general correspondence of 1884 with 1888, and of 1890 with 1888. In the latter pair we have two maxima coincident in time at the 15th week; then a more pronounced maximum in the 20th week of one year and the 21st of the other; then a deep cleft in both curves at the 28th week, while the remainders are generally alike.

Again, considering the intervals between pronounced maxima (40 cases), the most common length seems to be about six weeks; and about three-fourths of the whole are between five and nine weeks,

Another line of inquiry is as to what particular fixed times in the year such relative maxima and minima of sunshine tend to be incident. For apparently there is such a tendency. Perhaps a longer series than this of Greenwich is required to determine the matter satisfactorily, and I cannot profess to have worked it out on the present data; but attention may be called to the 21st week (about the end of May), which appears generally to be a sunny centre; while the 16th and 24th weeks have rather an opposite character.



Weekly Sunshine at Greenwich.

Once more, the general character of the curves seems to vary from time to time between complexity and simplicity. Thus the last pair may be described as simpler than those above; they have fewer distinct waves. (1889 is somewhat similar to its two neighbours here given). It is known that 1888 was a time of maximum sunspots, and 1889 one of minimum; and one

is disposed to ask, Might this have anything to do with the curious difference of type of the curves about those two years? The series is too short to warrant an opinion on the point; but perhaps the matter is worth looking into when more observations are available.

The general line of investigation suggested, then, is by a careful study of the entire series of such curves (since 1877) to form some idea (which appears to be possible) as to where those three weeks' relative maxima and minima of sunshine in a commencing or current year are likely to recur.¹

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

MAY 20th, 1891.

Ordinary Meeting.

BALDWIN LATHAM, M.Inst.C.E., President, in the Chair.

MICHAEL GEORGE FOSTER, M.A., M.B., Alassio, Riviera di Ponente, Italy; and JOHN ROBINSON, J.P., Westwood Hall, Leek, were balloted for and duly elected Fellows of the Society.

Mr. SYMONS stated that the subscriptions promised to the New Premises Fund amounted to £1,157 2s.

The following Papers were read :—

"ON THE VERTICAL CIRCULATION OF THE ATMOSPHERE IN RELATION TO THE FORMATION OF STORMS." By W. H. DINES, B.A., F.R.Met.Soc. (p. 208.)

"ON BROCKEN SPECTRES IN A LONDON FOG." By A. W. CLAYDEN, M.A., F.R.Met.Soc. (p. 209.)

"AN ACCOUNT OF THE 'LESTE,' OR HOT WIND OF MADEIRA." By H. COUPLAND TAYLOR, M.D., F.R.Met.Soc. (p. 217.)

Mr. SHELFORD BIDWELL, M.A., F.R.S., also exhibited an Experiment showing the effect of Electrification upon the condensation of Steam. (p. 258.)

JUNE 17th, 1891.

Ordinary Meeting.

BALDWIN LATHAM, M.Inst.C.E., President, in the Chair.

JEREMIAH JAMES COLMAN, M.P., Carrow House, Norwich;
ERNEST B. DUKOFF-GORDON, B.A., Allahabad, N.W. Provinces, India;
GEORGE EDWARD LEON, Bletchley Park, Bletchley;
THOMAS DE COURCY MEADE, M.Inst.C.E., The Park, Highgate, N.; and
FRANK RUSSELL, F.R.G.S., 16 Montrell Road, Streatham Hill, S.W.,
were balloted for and duly elected Fellows of the Society.

¹ I may state that I have made out curves for all those years, and they are to open inspection by any one who may wish to see them.

The following Papers were read :—

"A CURIOUS CASE OF DAMAGE BY LIGHTNING." By ALFRED HANDS, F.R.Met.Soc. (p. 226.)

"ON THE MEAN TEMPERATURE OF THE AIR AT THE ROYAL OBSERVATORY, GREENWICH, AS DEDUCED FROM THE PHOTOGRAPHIC RECORDS FOR THE FORTY YEARS FROM 1849 TO 1888." By WILLIAM ELLIS, F.R.A.S., F.R.Met.Soc. (p. 233.)

"ON THE COMPARISON OF THERMOMETRICAL OBSERVATIONS MADE IN A STEVENSON SCREEN WITH CORRESPONDING OBSERVATIONS MADE ON THE REVOLVING STAND AT THE ROYAL OBSERVATORY, GREENWICH." By WILLIAM ELLIS, F.R.A.S., F.R.Met.Soc. (p. 240.)

"PHONOMETER." By W. F. STANLEY, F.G.S., F.R.Met.Soc. (p. 250.)

"SOME SUGGESTIONS BEARING ON WEATHER PREDICTIONS." By ALEX. B. MACDOWALL, M.A. (p. 252.)

CORRESPONDENCE AND NOTES.

AN EXPERIMENT SHOWING THE EFFECT OF ELECTRIFICATION UPON THE CONDENSATION OF STEAM. By SHELFORD BIDWELL, M.A., F.R.S.

WATER is boiled in a small tin bottle, furnished with a cork through which passes a glass tube terminating in a nozzle of about 1-16th inch aperture. The shadow of the steam as it issues from the nozzle, when cast upon a white screen by a powerful light, appears under ordinary conditions to be of feeble intensity and of a neutral grey tint, showing that the steam is nearly transparent. But if a discharge of electricity is directed upon the base of the jet of steam by means of a bundle of needle points in connection with an influence machine, the shadow at once becomes dark and dense, at the same time assuming, especially near its edges, a peculiar orange-brown hue. The electrical discharge appears to act by promoting coalescence of the exceedingly minute particles of water contained in the jet, thus forming drops large enough to obstruct the more refrangible rays of light.

The experiment suggests a possible explanation of the intense darkness of thunder clouds, as well as of the lurid yellow glow by which such clouds are often distinguished.

FURTHER NOTE ON THE RELATIVE PREVALENCE OF DIFFERENT WINDS AT THE ROYAL OBSERVATORY, GREENWICH. By WILLIAM ELLIS, F.R.A.S., of the Royal Observatory.

THE paper which I communicated last year to the Royal Meteorological Society on the above question¹ was prepared with the object of showing whether the increased prevalence of North-east winds which Mr. Prince had found in recent years to exist at Crowborough was indicated also by the Greenwich records. In that paper I compared together the results obtained by Mr. Prince from one observation daily at 9 a.m., with results for Greenwich taking into account the whole twenty-four hours. This was done simply because the Greenwich results existed in such shape available for immediate use. Mr. Prince took exception at the time to the comparison made in this way, and indicated his belief, as I understood, that if the comparison of his results had been made with corresponding Greenwich results, that is with such as would have been obtained by discussion of the observed indication of the wind at 9 a.m. only, much of the discordance would

¹ *Quarterly Jour.*, Vol. XVI, page 221.

have disappeared. I am afraid that I may not have appeared to give due attention to his remarks on this point, one reason that weighed with me perhaps being that my examination of the Osler anemometer record, day by day, through a long series of years, had certainly not impressed me with any idea that the difference in the results found for the two places could be due to the circumstance that, in the discussion of the Greenwich winds, the whole day was considered, instead of 9 a.m. only.

In Mr. Prince's Report for the year 1890, of which he has kindly favoured me with a copy, I observe that he reiterates his objection to the method of comparison adopted. It seems, therefore, desirable to make the comparison in the way suggested by him. It happens that the Meteorological Report that we send daily to the Meteorological Office, and in other directions, includes the direction of the wind at 9 a.m. as taken from the anemometer record. These directions I have now discussed for the years 1885 to 1889 to which Mr. Prince again refers. Unlike the results before given, these have been tabulated as referred to sixteen points of the compass, instead of eight. And since it is not a new extraction from the Osler record that is now made, but simply the employment of the daily directions of wind as given in reports all prepared before the discordance mentioned by Mr. Prince was (in the year 1890) pointed out, any possibility of individual bias in the preparation of the results becomes removed. In saying this I cast no reflection, wishing simply to make clear the thorough independence of the Greenwich result.

TABLE I.—NUMBER OF DAYS OF PREVALENCE OF DIFFERENT WINDS IN EACH YEAR, 1885 TO 1889, AS DERIVED, AT 9 A.M. ON EACH DAY, FROM THE RECORDS OF THE SELF-REGISTERING OSLER ANEMOMETER OF THE ROYAL OBSERVATORY, GREENWICH.

Year.	N.	NNE	NE.	ENE.	E.	ESE.	SE.	SSE.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.	Calm.
1885	24	28	30	23	12	20	7	6	17	44	46	46	12	11	5	19	15
1886	20	20	31	25	12	16	7	6	20	37	45	59	18	11	2	17	19
1887	32	42	30	19	10	5	3	6	14	23	46	59	14	6	3	15	38
1888	27	32	31	12	13	12	6	12	18	41	46	53	14	12	10	7	20
1889	30	27	29	10	12	11	8	9	12	40	56	47	23	5	6	13	27
Mean	26	30	30	18	12	13	6	8	16	37	48	53	16	9	5	14	24

To reduce the numbers of Table I. to eight points of the compass, half the number of days of North-north-west wind, and half the number of days of North-north-east wind were in each year added to the number for the North wind, and so on. The results as referred to eight points are contained in Table II., adding thereto the previous Greenwich means, and also the Crowborough means.

TABLE II.—NUMBER OF DAYS OF PREVALENCE OF DIFFERENT WINDS AS GIVEN IN TABLE I. REFERRED TO EIGHT POINTS OF THE COMPASS.

Year.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
1885	48	55	34	20	42	91	40	20	15
1886	38	54	32	18	42	93	53	16	19
1887	61	60	22	9	28	87	47	13	38
1888	46	53	25	18	45	93	46	20	20
1889	50	48	22	18	37	99	49	15	27
Mean, Greenwich 9 a.m. direction	48	54	27	17	39	92	47	17	24
Mean from previous paper, Green- wich whole day direction	49	52	35	23	37	100	40	19	10
Mean, Crowborough 9 a.m. direction ..	41	102	21	22	38	72	50	17	..

By the substitution of the 9 a.m. direction for that for the whole day at Greenwich, the mean number of days of North-east wind becomes increased from 52 to 54, and the number of days of South-west wind decreased from 100 to 92, both changes, though small, being in the direction of bringing the numbers more into harmony with those of Mr. Prince. But the new Greenwich numbers for North-east and South-west winds are still widely different from those of Mr. Prince. The difference is, therefore, not to be explained in the way supposed. One curious point is that the numbers for other winds are in general in good agreement.

THE "IGNIS FATUUS," OR, WILL O' THE WISP. By F. RAMSBOTHAM, F.R.Met.Soc.

FOR some years now, since I have been living at the Warren, Crowborough, in Sussex, I have, in common with many others, been struck by seeing Will o' the Wisp, or *Ignis Fatuus*, playing about in the evening at various times, sometimes in one place, sometimes in another, and sometimes two at once, but not in the same place. Now I have observed that these appearances always coincide with unsettled weather, that is, that bad weather has invariably followed their appearance—in fact, it is quite a storm warning to us, as bad weather is sure to follow sooner or later, generally sooner.

On Saturday, September 26th, 1891, one of my brothers and myself watched one for some time, and last night (October 1st) it appeared in the same place and was visible quite half-an-hour. It does not dance about, but now and then takes a graceful sweep, now to quite a height, and then makes a gentle curve downwards, after sparkling and scintillating away for ten minutes or more.

In the winter there is generally a very remarkable one which appears to rise in Ashdown Forest beyond this estate, which I have known to keep steadily in the air for half-an-hour, and then sail away a long space and stop again. Our keeper has seen it dozens of times, and in every case bad weather followed.

SOUTH AFRICAN WEATHER 1890-91. By CHARLES COWEN.

MR. COWEN, in a letter from Johannesburg, dated April 1891, says:—"Nearly every mail from beyond the Equator to South African ports, for months past, has brought news of the phenomenal winter which has covered the European belt of the northern hemisphere, increased mortality to an unusual degree, and done vast damage to property.

"To readers on the northern side of the globe, it may be of interest to have attention drawn to what has been transpiring meteorologically on this side; and for some to consider whether beneficial results of any kind may be obtained by extending systematic observations to at least the principal parts of this Continent, now being widely embraced by the white race, in addition to what is done by the Meteorological Commission of the Cape of Good Hope, whose observers touch Bloemfontein in the Orange Free State, and Johannesburg and Rushenburg in the Transvaal.

"While the winter in Europe and North America has been one of greater hardness, and its range wider than has been known for many years, the corresponding period (our summer), in portions extending from Zambezia towards the Cape, has been remarkable for the rains and storms that have prevailed. They began in the Transvaal at an unusually early date; and I find that the Free State, Natal, the Transkeian Territory, and sections of the Colony had these early downpours as we have had them—often accompanied by high winds and heavy electric storms, with brief intervals to the present time. Many of these fierce storms synchronised with distressing snowfalls and extreme frost on the northern half of the globe (reported to us by cablegram).

"I do not give details here, because too many of them would be required to be of practical use to the readers of so brief a paper as this must be. Those who care to follow up the subject will find all the information at present recorded in the files of South African newspapers at the Royal Colonial Institute, the offices of the Agent-General for the Cape of Good Hope, Sir Charles Mills, K.C.M.G., the Crown Agents for Natal, and the Consuls-General in London for the South

African Republic and the Orange Free State. There too, they will find, at least with Sir Charles Mills—I do not know what the others may have—the Annual Reports of the Cape Meteorological Commission, and maps of rainfall for years past, with which they can compare as much information as a newspaper will give them of our latest seasons' rains. But the following may be mentioned here:—

"The rains on the East Coast and the high inland plateaux have been less steadily from the South-east than they usually were. The downpour has come from several quarters in succession, and everywhere more prolonged in duration and far greater in quantity than ordinarily.

"In Basutoland the rains were later than they should have been, but they have made up in quantity and persistence what they wanted in punctuality of recurrence.

"The wet season varies, of course, in South Africa, not only according to the latitude of the several countries, but to the usual physical conditions which affect the copiousness and the reverse of rains. But throughout the Continent the rains of 1890-91 have been excessive. What the averages will be, it is not possible to state at present. On the West Coast of the Cape Colony, a cold South Atlantic current sweeps; and on the East Coast, one so much warmer that at False Bay it is 15° higher in temperature than at Table Bay—a sandy, low level strip of land, 20 miles broad, separating the two Bays from one another."

Mr. Cowen then refers to the excellent work accomplished by the Cape Meteorological Commission, and suggests that much more information on the meteorological condition of the various countries of South Africa might be obtained if the interest and cooperation of several companies and gentlemen were secured in the matter.

He then goes on to say:—"Climatic conditions of new countries must influence emigration, and emigration trade. There are parts of the Transvaal equal to the most balmy lovely spots upon the globe, and some like Scotland, none like Manitoba or Labrador, but some valleys where fever reigns and people die, and some parts where longevity is common. There are portions of Bechuanaland where no white man should settle, and others again within its limits which would give new life to thousands of the over-crowded people of the United Kingdom; while parts of Mashonaland are described as a very land of Beulah, and certain river and coast stations as the grave of the white man.

"Under the existing seething condition of life in the mother country, when public thought is strained to know what best to do with the surplus population, it must surely be of some consequence to know also reliably the climatic character of the countries to which some of that surplus may be sent, and to devise machinery for regularly obtaining that information. Thus, for climatic reasons all whites have to clear out of part of the country towards portions of the Zambezia in November, if they will not leave their bones there. There is a time of the year when travelling by the Delagoa Bay route to and from the Transvaal is dangerous, and another when it may be done with impunity. So, too, with portions of this last-named grand country in which Britons have acquired millions of acres—some areas are notably healthy all the year round, others northward and eastward are to be avoided as one would avoid the Upas Valley of Java; and some of these Valleys of the Shadow of Death change their characters as fire and civilisation systematically approach them, just as the tsetse fly has disappeared with the extinction of large game."

THE METEOROLOGY OF SOUTH WEST AFRICA.

DR. H. SCHLICHTER, in a paper¹ on "The Geography of South West Africa," which was read at the recent Meeting of the British Association at Cardiff, gives the following account of the meteorology of that district, which is, however, only imperfectly known, as only quite recently meteorological observations have been commenced at some of the missionary stations.

There are two distinct seasons, viz. the hot or rainy and the dry. The former, in which most of the rain falls, lasts from November to May, and the latter

¹ *The Scottish Geographical Magazine*. Vol. VII. p. 484.

during the rest of the year. The rains seldom last long, but fall very heavily, and with the thunder which accompanies them, proceed regularly from east to west towards the Atlantic. In the dry season the sky is often cloudless for months together; but as a rare occurrence it has happened that, even in this part of the year, rain has fallen not only in Herero-land but also in the interior, on the highlands of the North-western Kalahari and the Omaheke. The meteorological phenomena near the Atlantic coast are in many respects analogous to those on the west coast of South America. The cold Benguela current coming from the south is the cause of the very low temperatures observed there; Walvisch Bay, for example, having an average annual temperature of 68° Fahr., and often bitterly cold nights. Cold mists rising from the sea at night time, and saturating everything with moisture, are of regular occurrence along the coast, to which, however, they are limited, very seldom being met with at Otjimbingue and other places more in the interior. To a certain degree these mists are the only substitute for the rain, which is almost entirely absent in the desert coast region. This absence is due chiefly to the West and South-west winds, which blow regularly for a longer or shorter period every day, and carry inland the little moisture which rises from the cold Benguela current, so that no rainfall near the coast is possible. But also the more eastern districts receive only irregular supplies of rain from this moisture, as the winds blow during the day, when the heat of the ground is usually very great, and, therefore, produces an upward current of air, so that thunderstorms and heavy rains are the chief characteristics of the wet season. It appears from this, that no definite distinction should be made between the meteorology of the central parts of Herero- and Nama-lands and that of the Kalahari Desert, as the winds are not dessicated by passing over high mountain ranges, but are without sufficient moisture from the above-mentioned circumstances. The scarcity of rains in the Kalahari is owing chiefly to its greater distance from the Atlantic: but that thunderstorms and heavy rainfall do occasionally occur in the eastern parts of the country, even in the neighbourhood of Lake Ngami, is recorded by various travellers. With regard to the distribution of the rainfall, it may be remarked that more falls in the northern than in the southern parts of South West Africa; and near the Orange River there are certain districts which are said to be entirely rainless.

RECENT PUBLICATIONS.

AMERICAN METEOROLOGICAL JOURNAL. A Monthly Review of Meteorology and Medical Climatology. July-September 1891. 8vo.

The principal contents are :—Franklin's Kite Experiment: by A. McAdie (11 pp.).—Cloud Heights and Velocities at Blue Hill Observatory: by H. H. Clayton (15 pp.).—Meteorological Kite-Flying: by W. A. Eddy (3 pp.).—The Samoan Hurricane of March 1889: by E. Hayden (15 pp. and 2 plates).—Mountain Meteorology: by A. L. Rotch (3 pp.). This contains extracts from a series of three lectures delivered before the Lowell Institute of Boston.—On the various kinds of Gradients: by L. Teisserenc de Bort (5 pp.).—The Climatic History of Lake Bonneville: by R. De C. Ward (7 pp.).—Water-Spouts: by Prof. Cleveland Abbe (4 pp.).—The Aspiration Psychrometer and its use in Balloons: by Dr. R. Assmann (6 pp.).—The Bergen Point Tornado: by W. A. Eddy (5 pp.).—The Hot Winds of California: by Lieut. J. P. Finley (6 pp.).—Altitude and Hay-fever: by Dr. W. J. Herdman (3 pp.).

CYCLONE TRACKS IN THE SOUTH INDIAN OCEAN, from information compiled by Dr. MELDRUM, C.M.G., F.R.S. Published under the Authority of the Meteorological Council. 1891.

This comprises a series of yearly charts showing the tracks which Dr. Meldrum has been able to lay down of all the cyclones in the South Indian Ocean for which he had received information as having occurred between the years 1848 to 1885. No reports of cyclones were received from Dr. Meldrum for the years 1849, 1850, and

1853. From the yearly series of charts has been prepared a monthly series, with a view of grouping together the storms occurring in the successive months of the year. The monthly charts are only nine in number, no cyclones having been recorded in either August or September, and the number in June and July being so limited that the information for these two months is shown on one sheet. In dealing with these cyclones Dr. Meldrum has divided them into "Progressive" and "Stationary." The very marked difference in the proportion of Progressive storms to those classed as Stationary in the different months of the cyclone season is a valuable fact for the seaman, if it can be considered established. The knowledge that in the early and late months of this season the chances are about even that a cyclone is stationary, and that in the height of the season the chances are very great that a cyclone is in rapid progression would greatly influence the action of a vessel that finds herself in the neighbourhood of a storm, but, though these proportions are too strongly marked throughout this long series of years to admit of much doubt that the ratio between the Progressive and Stationary Cyclones is different in the different parts of the season, the doubt whether full information of every storm has been obtained must prevent the proportions as herein given being accepted as absolutely correct.

The distribution of the available material, and the relative frequency, for the whole series of 33 years, for the several months are as follows :—

Month.	Progressive Storms.		Stationary Storms.		Totals.	
	Total.	Frequency.	Total.	Frequency.	Stationary and Progressive.	Frequency.
October	2	1 in 18 years	3	1 in 12 years	5	1 in 7 years
November	12	1 " 3 "	13	1 " 3 "	25	5 " 7 "
December	23	2 " 3 "	10	2 " 7 "	33	1 " 1 "
January	52	3 " 2 "	19	1 " 2 "	71	2 " 1 "
February	55	5 " 3 "	6	1 " 6 "	61	5 " 3 "
March	40	4 " 3 "	19	1 " 2 "	59	5 " 3 "
April	26	3 " 4 "	24	2 " 3 "	50	3 " 2 "
May	8	2 " 9 "	11	1 " 3 "	19	1 " 2 "
June	1	1 " 35 "	2	1 " 18 "	3	1 " 12 "
July	1	1 " 35 "	1	1 " 35 "	2	1 " 18 "
Yearly	220	..	108	..	328	..

DENKSCHRIFTE DER MATHEMATISCH-NATURWISSENSCHAFTLICHEN CLASSE DER KAISERLICHEN-AKADEMIE IN WIEN. Band LVIII. 1891. 4to.

Contains: Die Veränderlichkeit der Temperatur in Oesterreich: by Dr. J. Hann (80 pp.). This is a most elaborate discussion of the variability of temperature at the Austrian stations. It chiefly refers to the decade 1871-90, but in it we find the variability for Vienna for the 91 year period 1800-90. The most interesting portion of the paper is that dealing with the change of variability with height above sea level, as naturally in Austria the stations at high levels are comparatively abundant, and Dr. Hann is admittedly the highest authority on mountain climate. In contrast to our own islands we may say that he finds that sudden serious falls of temperature are more frequent than sudden rises of equal amount.

HEALTH: THE VOYAGE TO SOUTH AFRICA, AND SOJOURN THERE. 1891. 8vo. 78 pp. Maps and Illustrations.

The information in this book was collected and republished in a convenient form on the occasion of the assemblage in London in August 1891 of the International Congress of Hygiene and Demography, whom the manager of the Castle Mail Packets Company entertained at luncheon on board the South African Royal Mail Steamer *Drummond Castle*. The first part of the work deals with "The

Cape as a Health Resort," and contains papers on (1) The Cape Peninsula, by C. L. Herman, M.B.; (2) Graham's Town and the Eastern Districts, by the Hon. W. G. Atherstone, M.D.; (3) The Central Karroo Districts, by H. W. Saunders, M.B.; and (4) The Upper Karroo Plateau, by J. Baird, M.D. The second part contains a paper on "South Africa as a Health Resort," by E. S. Thompson, M.D., which has been reprinted from the Proceedings of the Royal Colonial Institute. Then follows an account of voyage out to South Africa, and other useful information.

METEOROLOGISCHE ZEITSCHRIFT. Redigirt von Dr. J. HANN und Dr. W. KÖPFEN. July to September 1891. 4to.

The principal contents are:—Zur Theorie der Cyklonen: von W. von Bezold (7 pp.). This is a summary of a Paper by the author in the *Sitzungsberichte* of the Berlin Academy for December 1890, in which he endeavours to explain cyclonic phenomena on the principles established by Hann and others, and attempts to reconcile the views as to descending whirlwinds held by M. Faye with the generally accepted ideas of modern meteorologists.—Mittheilungen aus dem Norwegischen Meteorologischen Institute: von H. Mohn (13 pp.). This is an account of the mode of discussion of meteorological results at present in practice in the Norwegian Institute.—A. Buchan über den täglichen Gang der meteorologischen Elemente auf dem Ocean und über die Vertheilung der Temperatur, des Luftdruckes und der Winde auf der Erdoberfläche: von Dr. J. Hann (12 pp.). This is a careful résumé of Mr. Buchan's report on Atmospheric Circulation.—Die Stürme der Adria: von R. R. von Jedina (12 pp.). This is an endeavour to explain the frequent storms of the Adriatic, and to show how to employ weather charts for their prediction.—Elektrische Beobachtungen auf dem Hohen Sonnblick: von J. Elster und H. Geitel (14 pp.). This is an account of a fortnight's experiments on Atmospheric Electricity, carried out by the authors on the Sonnblick and at Kulm-Saigurn, the station at the foot of that mountain. The results are of great interest to anyone investigating the subject, but we shall only extract what is said about St. Elmo's Fire. This appears with every thunderstorm, and is as often negative as positive. Whenever a flash is blue it is followed by negative, and when red by positive, St. Elmo's Fire.

REPORT ON THE METEOROLOGY OF INDIA IN 1889. By JOHN ELIOT, M.A., Meteorological Reporter to the Government of India. 4to. 640 pp. and 10 plates. 1891.

This is the fifteenth Report and the fifth of the second decade, and gives the results in the same form as in previous years of the observations recorded at 90 stations. The rainfall stations number 506. Mr. Eliot finds that "the meteorology of the three years—1887, 1888, and 1889—present many points of resemblance in their larger abnormal features, more especially in the following:—1. In each year the cold weather rains in the plains of Northern and Central India were favourable, and either normal or in moderate excess. They were most abundant in 1889. On the other hand, the snowfall over the Himalayan area was less than usual, and the snow accumulation undoubtedly below the normal. 2. Hot weather conditions in March, April, and May were more pronounced than usual, and produced the same large effects on the pressure distribution, the most important being increased pressure or positive pressure anomalies in Southern India, and deficient pressure or negative pressure anomalies in Northern India. 3. The conditions and distributions of pressure in May were in each year favourable to the early establishment of a strong and steady South-west Monsoon. 4. The rains were unusually steady from June to August, but withdrew suddenly from North-Western India (i.e. Punjab, Rajputana, Central India, and the western districts of the North-Western Provinces) very early in September. 5. The rainfall in Madras and Southern India, generally due to the retreating South-west Monsoon, was favourable in the years 1887 and 1888, and on the whole sufficient in 1889, except in the southern districts of Madras. 6. The rainfall distribution of the three years was, on the whole, favourable, and was sufficient for agricultural operations, except in the following areas, where droughts caused a partial or almost entire loss of the crops, viz. 1887, Partial drought in Guzerat and Kathiawar; 1888, Severe and prolonged drought in

Ganjam and South Orissa and the adjacent hill districts, which resulted in famine, and partial drought and failure of the crops in a small narrow area in North Behar; 1889, Partial drought and failure of the crops in the southern districts of Madras, more especially Tinnevely, Madura, Trichinopoly, and Coimbatore."

SITZUNGSBERICHTE DER KAISERLICHEN AKADEMIE DER WISSENSCHAFTEN IN WIEN. Bd. C. Abth. II. April 1891. 8vo.

Contains: Studien über die Luftdruck- und Temperaturverhältnisse auf dem Sonnblickgipfel, nebst Bemerkungen über deren Bedeutung für die Theorie der Cyclonen und Anticyclonen: von Dr. J. Hann (86 pp.). This a discussion of the barometrical and thermometrical extremes registered at the top of the Sonnblick (10,200 ft.) as compared with the simultaneous readings at Ischl during the past four years. Dr. Hann finds that in winter barometrical maxima above are always associated with maxima at the lower level. In winter also the changes of temperature on the summit, which accompany the passages of anticyclones and cyclones respectively, are exactly opposite to those observed at lower levels. The greater part of the communication is taken up with a reply to some criticisms of the author's views on the origin of cyclones, &c., which have appeared in *Science* during last winter.

SYMONS'S MONTHLY METEOROLOGICAL MAGAZINE. July to September 1891. Nos. 806-808. 8vo.

The principal Articles are: Producing Rain artificially (2 pp.).—The United States Weather Bureau (2 pp.).—The Theory of Halos and Parhelia: by T. W. Backhouse and Rev. A. K. Cherrill (3 pp.).—Sunshine Recorders: by J. Baxendell (1 pp.).—On Cloud at Greenwich (2 pp.).—Indian Monsoon Forecasts (4 pp.).—Sunshine and Sunlight: by F. C. Bayard (1 p.).—Something like a Shower: by G. J. Symons (1 p.).—Meteorological Bibliography: by G. J. Symons (4 pp.).—A Rainy August (7 pp.).

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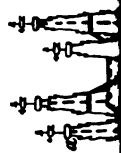
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THE END.

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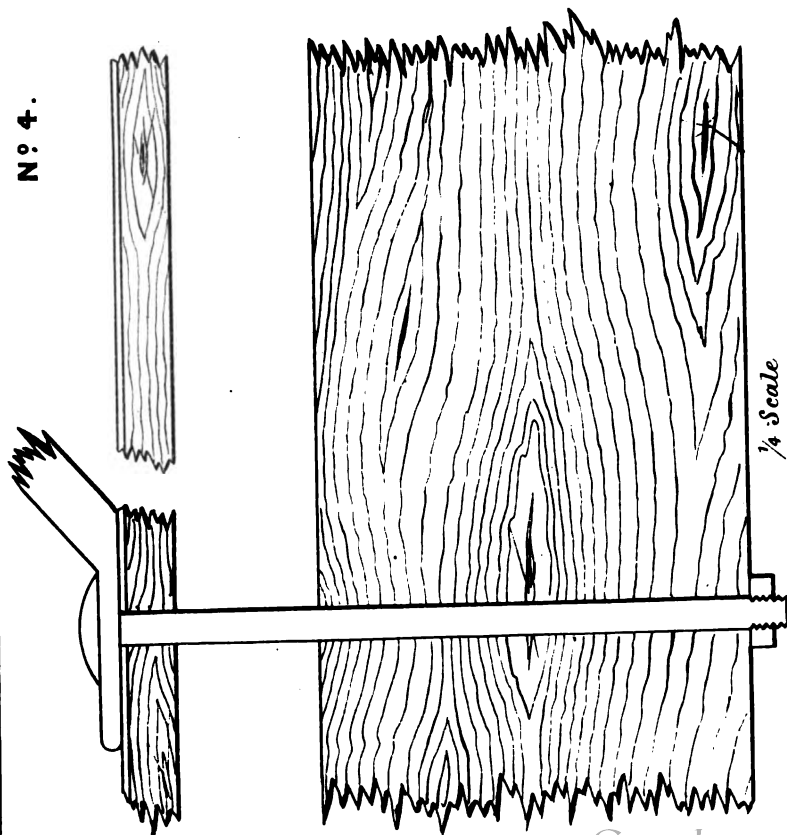


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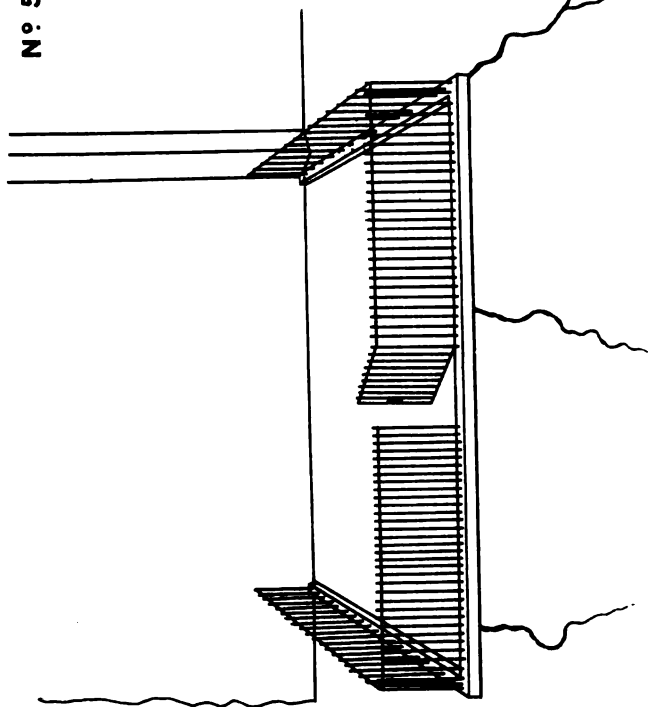
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